

**Proceedings**  
**of the 3rd International Yellow River Forum**  
**on Sustainable Water Resources Management**  
**and Delta Ecosystem Maintenance**

Volume III

# The 3rd International Yellow River Forum on Sustainable Water Resources Management and Delta Ecosystem Maintenance

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# Welcome

I, On behalf of the Organizing Committee of the 3rd International Yellow River Forum (IYRF) on Sustainable Water Resources Management and Delta Ecosystem Maintenance and the conference host, Yellow River Conservancy Commission (YRCC), warmly welcome you all over the world to Dongying to attend the 3rd IYRF.

Yellow River Conservancy Commission hosted the 1st and 2nd IYRF successfully in Zhengzhou in October of 2003 and October of 2005, respectively. The central theme of the 1st IYRF is “River Basin Management” and the 2nd IYRF is “Keeping Healthy Life of the River”, which got high response and big support from water field around the world. We still remember, on the plenary and technical sessions of the past two forums, delegates carried on wide exchanges and discussions, which showed their latest research achievements sufficiently and analyzed the experiences of river harnessing and river basin management from different aspects. We collected all the valuable viewpoints and advanced experiences presented on the forum into proceedings, which promote the river basin management to keep healthy life of the river and scientific research etc. actively.

The central theme of the 3rd IYRF is sustainable water resources management and delta ecosystem maintenance. It is developed into eight sub - themes: (1) sustainable water resources management and basin ecosystem construction; (2) delta ecosystem protection and maintenance; (3) delta ecosystem and delta development modes; (4) strategies and practices on keeping healthy life of rivers; (5) river engineering and river ecology; (6) regional water resources allocation and interbasin water transfer; (7) water right, water market and water - saving society; and (8) high - tech application in modern basin management and its development trend. The Conference also arranges 18 special sessions jointly hosted by YRCC and the international well - known organizations as follows: Sino - Hispanic Water Forum; Sino - Dutch the 8th Joint Steering Committee; EU - China River Basin Management Programme; WWF - Integrated River Basin Management Forum; GWP High - level Forum on Sustainable Water Resources Management and Delta Ecosystem Maintenance; Sino - Norwegian Seminar on Sustainable Water Management; DFID - Special Session on Water and Soil Conservation; Yellow River Basin CPWF Workshop; EURO - INBO Special Session; Sino - Italian Cooperation Project on Environmental Protection; GWSP Session; Global Climate Change and

Water Resources Risk management of the Yellow River Basin; Sino – Dutch Project; Environmental Flow and Environment Protection for River Delta & Sino – Dutch Environmental Flow Training; Sino – Dutch Cooperation Project on “Satellite Based Water Monitoring and Flow Forecasting System in the Yellow River Basin”; Special Session of International Centre of Excellence in Water Resources Management (ICE WARM) Maximising the Benefits of Professional Development Activities; Post – evaluation Session on UNESCO – IHE – YRCC Professionals Training Program; Water Resources Allocation in China; Water Engineering Construction and Management in River Basins; and Management and Safety for Water Supply.

At present, about 800 experts and scholars from 64 countries and regions have registered for participating in the Forum and submitted more than 500 papers. After examined by the Scientific Committee, more than 400 papers are collected into the proceedings of the 3rd IYRF. Compared with the past two forums, the content of the 3rd forum is more abundant and the form of sessions is more multiform. The Conference will omni – directionally show the achievements on water conservancy of China and the Yellow River basin management, deeply discuss the focus and crux of river basin management, and hope to develop a mechanism for international cooperation and exchange more widely.

I am sure that with the effort of the Advisory Committee, the Organizing Committee, the Scientific Committee and all of the representatives will benefit from the conference in the professional field, and have a good time in Dongying. I believe that your experiences exchanged and your good suggestions for sustainable water resources management and delta ecosystem maintenance in the conference will influence the management of Yellow River and other river basins in the world actively in future.

Finally, I hope the 3rd IYRF be successful; hope the conference make a strong impression to every participant; and hope every participant be in good health and have a pleasant stay in Dongying.

Li Guoying

Chairman of the Organizing Committee, IYRF

Commissioner of Yellow River Conservancy Commission, MWR, China

Dongying, China, October 2007

## Foreword

The International Yellow River Forum (IYRF) is a great event in water field, also a good chance for scientists who are engaged in river basin management, hydraulic research and management to exchange and discuss the river basin management and the science of water.

The 3rd IYRF is held on October 16 ~ 19, 2007 in Dongying, China. The central theme focuses on; Sustainable Water Resources Management and Delta Ecosystem Maintenance. The central theme involves the following eight sub – themes;

- A. Sustainable water resources management and basin ecosystem construction;
- B. Delta ecosystem protection and maintenance;
- C. Delta ecosystem and delta development modes;
- D. Strategies and practices on keeping healthy life of rivers;
- E. River engineering and river ecology;
- F. Regional water resources allocation and interbasin water transfer;
- G. Water right, water market and water – saving society;
- H. High – tech application in modern basin management and its development trend.

Eighteen special sessions jointly hosted by YRCC and relevant governments and well – known international organizations are arranged on the 3rd IYRF as follows:

- As. Sino – Hispanic Water Forum;
- Bs. Sino – Dutch the 8th Joint Steering Committee;
- Cs. EU – China River Basin Management Programme;
- Ds. WWF – Integrated River Basin Management Forum;
- Es. GWP High – level Forum on Sustainable Water Resources Management and Delta Ecosystem Maintenance;
- Fs. Sino – Norwegian Seminar on Sustainable Water Management;
- Gs. DFID – Special Session on Water and Soil Conservation;
- Hs. Yellow River Basin CPWF Workshop;
- Is. EURO – INBO Special Session;
- Js. Sino – Italian Cooperation Project on Environmental Protection;
- Ks. GWSP Session; Global Climate Change and Water Resources Risk Management of the Yellow River Basin;
- Ls. Sino – Dutch Project; Environmental Flow and Environment Protection for

River Delta & Sino – Dutch Environmental Flow Training;

Ms. Sino – Dutch Cooperation Project on “Satellite Based Water Monitoring and Flow Forecasting System in the Yellow River Basin” ;

Ns. Special Session of International Centre of Excellence in Water Resources Management ( ICE WaRM ) Maximising the Benefits of Professional Development Activities;

Os. Post – evaluation Session on UNESCO – IHE – YRCC Professionals Training Program;

Ps. Water Resources Allocation in China;

Ar. Water Engineering Construction and Management in River Basins;

Br. Management and Safety for Water Supply.

The preparation work for the 3rd IYRF was started after the 2nd IYRF. Since the Bulletin one was released, more than 500 papers have been submitted by about 800 decision – makers, experts and scholars from 64 countries and regions. Through the examining of the Technical Committee, more than 400 papers are collected into proceedings, including 322 papers are put into the following six volumes:

Volume I: including 52 papers under the sub – theme A

Volume II: including 50 papers under the sub – theme B and C

Volume III: including 52 papers under the sub – theme D and E

Volume IV: including 64 papers under the sub – theme E

Volume V: including 60 papers under the sub – theme F and G

Volume VI: including 44 papers under the sub – theme H

After the forum, Volume VII and VIII will be published, including about 100 papers. Total more than 300 papers are selected to present in 77 technical sessions and 5 plenary sessions.

We appreciate the generous supports of the co – sponsors, especially Dongying Municipal Government of Shandong Province, Shengli Petroleum Administrative Bureau of China, EU – China River Basin Management Program, Yellow River Water & Hydropower Development Corporation ( YRWHDC ), Comprehensive Development Bureau of MWR, Yellow River Wanjiashai Water Multipurpose Dam Project Co. Ltd, Ministry of Environment of Spain, WWF ( World Wide Fund for Nature ), UK Department for International Development ( DFID ), Global Water Partnership ( GWP ), World Bank ( WB ), Asian Development Bank ( ADB ), Challenge Program on Water and Food ( CPWF ), International Network of Basin Organizations ( INBO ), National Natural Science Foundation of China ( NSFC ), Tsinghua University ( TU ), China Institute of Water Resources and Hydropower Research ( IWHR ), Nanjing Hydraulic Research Institute ( NHRI ), International Economic

Technical Cooperation and Exchange Centre of MWR (IETCEC, MWR).

We also would like to thank the members of the Advisory Committee, the Organizing Committee and the Scientific Committee, and all the authors presented in the proceedings for their outstanding contributions.

We sincerely hope that the publication of the proceedings of the 3rd IYRF will give an active impulse to the sustainable water resources management and delta ecosystem maintenance.

Shang Hongqi

Secretary General of the Organizing Committee, IYRF

Dongying, China, October 2007

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# **Strategies and Practices on Keeping Healthy Life of Rivers**

# Contemplation for Floodplain Problems in the Lower Yellow River

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**Abstract:** This paper deals with the basic situations of floodplain in lower Yellow River and discussed the status of flood plain of Yellow river as well as the role played in flood control, meanwhile it analyzed main existing problems for the nonce. It brought forward the persistence of water and sands regulations and continual enlargement of flow capacity in main channel and optimization of reservoir regulations while reducing probability of flood over flow during small and middle size discharge. So, it should speed step of safety construction of floodplain. Flood plain in lower Yellow River should enjoy the four suggestions on flood detained area compensation policy. By water and sand regulations and optimization of reservoir regulation as well as safety construction of floodplain, it renders the flood overflow probability to occur once three to five years and the overflow probability of village protecting platform reaches once twenty years. Through the compensation policy on flood detained area of our country it can fundamentally solve the problems of residing habitants in floodplain and flood control in lower Yellow River and constructs the harmony society of floodplain.

**Key words:** the Lower Yellow River, water and sand regulations, mid - flow regulations, floodplain construction, policy compensation

## 1 Outline of floodplain in Lower Yellow River

### 1.1 Natural geography situations

From Baihe town of Mengjin county of Henan province to river mouth in Lijin county of Shandong province in the Lower Yellow River, the total river length is 878 km. The total area of lower river is 4,647 km<sup>2</sup> (including 407 km<sup>2</sup> of Fengqiu inverse irrigation area, same as follows). The river takes on multiple styles and flood plain area is 4,047 km<sup>2</sup>. The area in the Lower reach accounts for 87% of total area.

The river is wide in upper reach and narrow in lower reach. Most part of floodplain is located in upper reach of Taochengpu site, and the area is 3,188 km<sup>2</sup> accounting for 79% of total area.

In terms of area of flood plain, the single dimensions of flood plain can be divided into follows, area number over 100 km<sup>2</sup> is seven (including one of Fengqiu inverse irrigation area), area number during 50 ~ 100 km<sup>2</sup> is nine, area number during 30 ~ 50 km<sup>2</sup> is twelve, area number underneath 30 km<sup>2</sup> is over ninety. The gradient is steeper at upper reach and gentler at lower reach, from 0.265‰ to 0.1‰. The discharge capacity is bigger at upper reach and less at lower reach. The defense standard of dike design is from 22,000 m<sup>3</sup>/s to 11,000 m<sup>3</sup>/s. River section from Baihe town to railway bridge of Beijing to Guangzhou is ancient route of Yu king, the length is 98 km, it belongs to meandering river shape, the river breadth is from 4.1 km to 10.0 km.

The floodplain area in this section is 580 km<sup>2</sup> in which the Wenmeng floodplain is 519 km<sup>2</sup>. To protect migrations from Xiaolangdi reservoir, the protection levees at upper reach of Dayulan project is built, the defense standard of which is 10,000 m<sup>3</sup>/s. It is equivalent to defense standard once in hundred years after Xiaolangdi reservoir use.

From railway bridge of Beijing to Guangzhou to Dongbatou river section is old flow route in Qing dynasty in length 131 km. The river is wide and shallow and belongs to typical meandering type. The breadth between two dikes is from 5.5 km to 12.7 km, the channel width from 1.5 km to 7.5 km, the floodplain area is 848 km<sup>2</sup>. The high floodplain formed after breach in Tongwaxiang section in 1855 is not high any longer through deposition of main channel of 150 years. This river

floodplain is average from 4 m to 5 m higher than two sides of ground, the highest is over ten meters, the suspended river problem is projecting. By statistics of river section analysis, it is 0.28 m to 2.38 m higher than floodplain level of left bank, the average is 1.12 m, the average transverse gradient is 0.333‰, larger than lengthways one.

Part of sections water level of right bank equal to floodplain located at front of river. Other water level equal to floodplain is higher 0.26 m to 2.11 m than floodplain at front of river, average is 0.42 m, the mean transverse gradient is 0.121‰ less than lengthways one. The river section of suspended problem is of no severity.

The reach from Dongbatou to Taochengpu is formed after breach of site Tongwaxiang in 1855, the total length of which is 235 km. the width between two banks is from 1.4 km to 20 km, the channel width is from 1.0 km to 6.5 km. The area of this river floodplain is 1,760 km<sup>2</sup> and it is main flood peak cutting area in lower reach. The floodplain is 2 m to 3 m higher than ground of outside river. The average is 2.5 m and the highest is 5 m during which the length is 70 km and river width is from 5 km to 20 km. At the reach, main flow is meandering, and as so called bean curd waist river section. The water level paralleled to floodplain is 0.52 m to 2.98 m, the mean transverse gradient is 0.515‰, it is obvious larger than lengthways one. Water level paralleled to floodplain is 0.63 m to 4.34 m higher than river front. The mean is 2.09 m. transverse gradient is 0.584‰, and obviously higher than lengthways one. In this river section, the floodplain width is large and the transverse gradient is sharp, so the secondary suspended river is the severest.

From Gaocun to Taochengpu, the river reach is 165 km in length. The river width is 1.4 km to 8.5 km, belonging to meandering river shape. Water level paralleled to floodplain is 1.08 m to 3.43 m higher than river front. The mean transverse gradient is 0.98‰, obviously larger than lengthways one. The water level of right bank paralleled to floodplain is 0.84 m to 2.78 m higher than river front floodplain, the mean is 2.15 m, the transverse gradient is 1.039‰, also larger than lengthways one obviously. During this reach the floodplain width is little narrow and transverse gradient is large. The secondary suspended river situation is also severe.

From Taochengpu to Yuwa, the reach length is 350 km, the space of two banks is 0.4 km to 5.0 km, the channel width is 0.3 km to 1.5 km, and it formed after Tongwaxiang breach under conditions of breach changed its route and occupied Daqinghe River. This reach has been trained as meandering shape and the flow route is much steady. The difference of floodplain and channel is larger and the floodplain area is 859 km<sup>2</sup>. Except for some larger floodplain in Changqing county and Pingyin county, others are all little floodplain areas. During this reach, the river gradient is little and the floodplain is narrow. The floodplain is 2 m to 4 m higher than ground outside river. The mean is 3 m. The largest is 7.6 m. In this reach, the water level paralleled to floodplain is 0.1 to 2.75 m higher than river front, and the average of two banks is 1.5 m or so. Because of narrow floodplain, the transverse gradient is larger, the largest is over 3.0‰. It should not ignore the secondary suspended river.

The reach from the lower Yuwa is 64 km in length, and it belongs to river mouth area.

## 1.2 Social and economical and calamity situations

The floodplain in the lower Yellow River is involved in Henan and Shandong provinces, including fifteen cities and forty three counties. By the end of 2003, there are altogether 1,924 villages, population of 1.79 million and 0.25 million km<sup>2</sup> of cultivated land. Among which there are 1,156 villages, population of 1.16 million km<sup>2</sup> and 0.16 million km<sup>2</sup> of cultivated land in Henan province, meanwhile, there are 768 villages, population of 0.63 million and 0.09 million km<sup>2</sup> of cultivated land in Shandong province.

It is typical agriculture economy in floodplain. Save some oil drills, there is no industry basically. The crops are mainly wheat, bean, corn and cotton. By statistics in 2002, the total production of food is 2.09 million t, among which the summer food is 1.13 million t, the autumn food is 0.95 million t, the average income is 600 to 2,200 Yuan RMB. By incomplete statistics, from 1949 to 2000, there were altogether twenty times of different flooding calamities, the people

who were suffered from calamity is 8 millions and the inundated area is 1.7 million km<sup>2</sup>. The heaviest year that suffered calamity is 1958, 1976, 1982 and 1996. Among which the year 1958, 1976 and 1982, the floodplain lower Dongbatou were all overflow, part of area upper Dongbatou was inundated. In Aug. 1996, the flood peak discharge in Huayuankou was 7,860 m<sup>3</sup>/s. because of heavy sediments deposition, the water level was extremely high and resulted in inundation of over one million people in lower river and 0.16 million km<sup>2</sup> of cultivated land was inundated. Meanwhile, during period of frozen or melting time, water level rises due to ice block and floodplain was endangered by ice floods.

### 1.3 Floodplain safety construction

China always sets importance on safety construction of floodplain in the Lower Yellow River. Since 1958, the productive levees have been built up widely. Because of block water of them, it is recognized that it had adverse influence on flood control.

In 1974, China State Council demanded to implement the policy of eliminating productive levees and building village protecting platform and carrying on strategy of "one water, one wheat on condition the sufficient food within a year" in the long run. After that, masses started to build protecting works designedly. The investment used in building protecting works is mainly from masses themselves and government provides a properly subsidy. Before 1982, the protecting works were mainly common platform and house terraces. There were no houses on common platform. The average area is 3 m<sup>2</sup> per person, and it used as protection facilities temporarily whenever floods come. Because the single house terrace is weak in resisting floods, the common terrace is not convenient, in 1982, they started to construct combined terrace and built some gravel roads and pitch ways as well as retreating boats and saving facilities. According to needs of flood control, in 1990, government set alert system in floodplain in lower reach. After 1996, government reinforced investment of floodplain. In light of standard of 60 m<sup>2</sup> to 80 m<sup>2</sup> per capita large terrace were set up and people were immigrated to outside in plan. By end of 2000, the migrated villages are 176 and population is 0.093,5 million. Among which, there were 9 villages and 4,600 people in Henan province, while in Shandong province, there were 88,900 people. The area of protecting works is 73.55 million m<sup>2</sup>, the built earth quantity is 140.55 million m<sup>3</sup>, and the retreat ways is 1,117 km in total length.

## 2 Floodplain status and flood controlling function in the Lower Yellow River

### 2.1 Floodplain status in the Lower Yellow River

The two dikes of floodplain in lower Yellow River is respectively the watershed of Yellow River and Huaihe as well as Yellow River and Haihe. The protecting area of two bank is 120,000 km<sup>2</sup> and there are over 110 cities, the protected population is 80 million, so it must ensure the safety of Yellow River dike. The floodplain between two dikes is formed due to river breach, meandering deposition and dikes building. The area of floodplain is over 4,000 km<sup>2</sup>, the habitants is 1.8 million. So, the floodplain in lower reach is flood way and detaining area and sediments depositing place, and it is also place where masses settle down and live, it equal to flood detained area of other river basin.

### 2.2 Flood controlling functions of floodplain in the Lower Yellow River

#### 2.2.1 Function of flood evolution

After overflow of floodplain, the channel is main flood way owing to little roughness coefficient and powerful flood capacity, but it should not ignore the flood capacity of floodplain. From Table 1, we may see that the discharge flowed in floodplain accounts for 10% to 45% of total discharge. The proportion of flood capacity is relevant to section shape, generally it accounts for 20%.

**Table 1 Discharge proportion measured during several floods in main hydrometeorological stations**

Time	Huayuankou		Gaocun		Sunkou	
	Discharge of section (m <sup>3</sup> /s)	Ratio of discharge overflow floodplain (%)	Discharge of section (m <sup>3</sup> /s)	Ratio of discharge overflow floodplain (%)	Discharge of section (m <sup>3</sup> /s)	Ratio of discharge overflow floodplain (%)
1958.7	11,500	14	17,400	38	15,900	45
1982.8	14,700	20	12,300	21	10,000	36
1996.8	7,860	11	6,810	31	5,680	44

### 2.2.2 Flood peak cutting function

The floodplain in lower reach of Yellow River has character of large area and much space, the function of cutting flood peak is very obvious. For example, in 1954, 1958, 1977 and 1996, the flood peak cutting situations of every sections in lower reach are shown compared with Huayuankou station as Table 2.

**Table 2 Flood peak cutting contrast table for several floods in every river sections in the Lower Yellow River**

Year	Huayuankou		Jiahetan		Gaocun		Sunkou	
	Flood peak discharge (m <sup>3</sup> /s)	Flood peak discharge (m <sup>3</sup> /s)	Flood peak cutting ratio (%)	Flood peak discharge (m <sup>3</sup> /s)	Flood peak cutting ratio (%)	Flood peak discharge (m <sup>3</sup> /s)	Flood peak cutting ratio (%)	
1954	15,000	13,300	11.3	12,600	16.0	8,640	42.4	
1958	22,300	20,500	8.1	17,900	19.7	15,900	28.7	
1977	10,800	8,000	25.9	6,100	43.5	6,060	43.9	
1982	15,300	14,500	5.2	13,000	15.0	10,100	34.0	
1996	7,860	7,150	9.0	6,810	14.4	5,800	26.2	

From table above, only the reach of 319 km from Huayuankou to Sunkou of wide river cut more than 26% of flood peak cutting, the cutting effect is very obvious. During flood of 1958 and 1982, the peak discharge at Huayuankou was respectively 22,300 m<sup>3</sup>/s and 15,300 m<sup>3</sup>/s. The peak discharge arrived at Sunkou was respectively 15,900 m<sup>3</sup>/s and 10,100 m<sup>3</sup>/s, the cutting percentage was respectively 28.7% and 34.0%. The largest storing capacity from Huayuankou to Sunkou is respectively 2,590 million m<sup>3</sup> and 2,450 million m<sup>3</sup>, which equal to total amount of Guxian and Luhun together. Because of flood peak cutting function of floodplain in lower reach, it greatly lessened tension of narrow river flood control and utilization probability and drainage discharge of Dongpinghu lake.

### 2.2.3 Sediments depositing function

Water quantity is lesser while sediments is in great deal, and relation of water and sediments is not in harmony. For a long time, great amounts of sediments deposited in channel, thus, the riverbed arise continuously and the suspended river developed. By statistics, since 1950 to 1998, the deposited sediments in lower reach is 9,200 million t during which the sediments on floodplain is 6,370 million t, the sediments in main channel is 2,830 million t. The deposition in floodplain



accounts for 69.2% of total.

Therefore, the suspended river situation would be more severe without deposition in floodplain, the river will deposit more sharply than before. The character of water and sediments will be difficult to change, in future there will be much more sediments deposit in lower reach. The position of floodplain is difficult to replace.

Meanwhile, due to water flow is lowly after flood enters into floodplain, by transverse exchange of water flow, a great amount of sediments deposited in floodplain. When clear flow enter main channel, it will enforce the scouring of main channel through deposition of floodplain and further enlarge the main channel capacity.

### **3 Existing problems of floodplain in the Lower Yellow River**

#### **3.1 Suffering from long term flood attack in floodplain and economy development lagging behind**

The floodplain is a living and productive place on where the masses depend. Constrained by nature special surroundings, there are hardly any industries, belonging to typical agriculture economy. Because flood in summer and autumn often inundates, the floodplain suffers from calamity usually. The autumn crop is in low production and yield is low and unsteady. Many villages migrated for times and living houses collapsed often, the living condition is quite badly. The life and fortunes are often menaced, thus, the economy and culture development lag behind. By statistics, masses' income in floodplain cannot obtain to 50% of local people average. At present, there are six provincial poor counties and three national poor counties, this is badly fitting to needs of affluent society construction.

#### **3.2 Floodplain safety construction lagging behind**

Since the policy of dike abolishing and building platform issued by State Council in 1974 on file 27 th, it has achieved some progress, and it had played certain roles in stabilizing masses' feeling and tackling basic living facilities and ensuring the safety of life and fortunes. Because the floodplain is wide in area and large in population and projects task is large, particularly in arise of riverbed due to sediments, the protecting works always cannot obtain to designed standard.

Firstly, the village protection height is not enough. 95% of protecting works cannot be congruent to the requirement of once in twenty years when Huayuankou discharge gets to 12,370 m<sup>3</sup>/s. Secondly, the area is not sufficient. At present, average area per person gets to 40 m<sup>2</sup>. It is not fitting to needs of 60 m<sup>2</sup> to 80 m<sup>2</sup> per person, particularly, there are no village protecting platforms of floodplain in most places at upper reach of Dongbatou

#### **3.3 Policy on floodplain being not adaptable to social and economical development presently**

The main policy issued by State Council in file 27 th in 1974 is that the productive levees must be down away with and set up village protecting platform and carried on one water and one wheat under condition of sufficient food kept for whole year. This policy has played some part for floodplain masses livings during planning economy period under condition that most districts did not settle down the basic problem of cloth and food. With the development of society and economy, particularly in canceling agriculture tax, the floodplain policy doesn't meet the needs of people's product and social development by far. Because of needs of flood control, the economy development was strictly held back. The difference between floodplain area and surrounding districts becomes larger and larger. The floodplain area is already the poorest area in Henan and Shandong provinces even the poorest in whole country. This is not fitting to the concept of harmonious society and people prime notion.

### 3.4 Contradiction between floodplain development and flood control being protrudent

Because the floodplain policy can not be implemented, the masses' living cannot be ensured, the masses built up a lot of productive levees in order to develop production. Thus, the productive levees were always repeating demolish and rebuild, even it becomes much more severe.

Due to existence of productive levees, it made the river flood route narrowly and has impacted on exchange of water and sands and made the sediments deposition sharply. So, the lower river reach channel becomes higher than floodplain and floodplain becomes higher than ground outside river, thus formed suspended river. This deteriorated flood control situations in lower Yellow River.

## 4 Suggestions for floodplain harness in the Lower Yellow River

### 4.1 Persisting in water and sand regulations and magnifying and keeping capacity of discharge evolution in main channel unceasingly

From 2002 to 2006, YRCC implemented three times of testing regulation of water and sands and two times of productive operation of water and sands regulations. The total water quantity of five times entered sea is 20.829 billion  $\text{m}^3$  and the sediments 122 million t. It obtained to scour main channel along total river line. The total sediments entered sea is 383 million t and the scouring sediments in lower reach is 273 million t. The minimum discharge capacity already restored from 1,800  $\text{m}^3/\text{s}$  of 2002 to 3,500  $\text{m}^3/\text{s}$  and achieved desired result. Therefore, we should keep on it. We utilize the reservoir capacity of water and sands regulations of Xiaolangdi and fully use the sediments transportation flow and gather the artificial flood peak to enhance the scouring effects and make flow capacity restore to 4,000  $\text{m}^3/\text{s}$  as soon as possible. And we should keep on it for long term and match to river training projects in order to fashion into flow route under middle sized flood.

### 4.2 To optimize reservoir regulations and reduce probability of overflow during little and middle discharge

As to future regulation of Xiaolangdi reservoir, the flow into the Lower Yellow River may be controlled with three classes. Firstly is ecological and water supply regulation. The goal is to meet the needs of irrigation and ecological water use in order to ensure no drying in main channel. Secondly is water and sand regulation. It should control flood peak no surpassing or approaching flow capacity of main channel and realize the goal of no scouring and no depositing in order to keep the flow capacity of main channel in lower reach. Thirdly is flood control regulation. When overflow floodplain flood occurs or high concentration sand flood at upper reach of Tongguan, the reservoir should be enlarged the discharge and fully release the sediments in order to realize the goal of floodplain deposition and channel scouring.

As regards of lower big flood, its sediments concentration is little. According to flood result during Xiaolangdi reservoir and Huayuankou estimated by General Planning Institute, the discharge of once in four years from Xiaolangdi, Luhun and Guxian to Huayuankou is 3,030  $\text{m}^3/\text{s}$ , the discharge of once in five years is 3,650  $\text{m}^3/\text{s}$ .

After construction of Zhangfeng reservoir and Hekoucun reservoir in Qin river, the flood peak will further reduce at lower reach of Xiaolangdi where is not under control. As for upper large flood, the peak floods over 6,000  $\text{m}^3/\text{s}$  and 8,000  $\text{m}^3/\text{s}$  are respectively five years and one year in Tongguan station since Longyangxia reservoir storing water from 1986 to 2005, the average probability is respectively once four year and twenty year. During the twenty years the biggest average discharge per day over 6,000  $\text{m}^3/\text{s}$  is zero. There are three years when discharge of largest average is between 4,000  $\text{m}^3/\text{s}$  to 6,000  $\text{m}^3/\text{s}$  and sediments load over 200  $\text{kg}/\text{m}^3$ . When the minimum discharge capacity kept in main channel is 4,000  $\text{m}^3/\text{s}$ , it can utilize regulation of reservoir to reduce overflow of middle sized discharge on floodplain and realize the probability of

once three to five years of overflow floodplain in the Lower Yellow River reach, this nears to inundation compensation standard of reservoir resettlement.

### **4.3 Accelerate step of floodplain safety construction**

There are much people and wide cultivation in the Yellow River floodplain. It is not practical and no necessary for the all people to migrate from floodplain to outside. The reason why not practical is that it is difficult to find sufficient relocation capacity to settle down these masses. The reason why no necessary is that there is cultivation resources of over 4,000 km<sup>2</sup> to be developed. At same time, according to sample investigation of twenty three thousands people who live in floodplain, only twenty percent people have willingness to migrate outside, most people are apt to settle down in floodplain by constructing village protecting platform. Therefore, the floodplain safety construction should be carried on with various manners, and settling down locally is principal. To move village near dike to outside and gather other villages to set up central town, and build up security platform according to flood coming odds of once in twenty years is as good as building migrations criterion of reservoir.

### **4.4 To enjoy compensation policy on flood detained area as soon as possible**

There are characters of flood detain, water store and sediments deposit in the floodplain of the Lower Yellow River reach and it occupies very important position in flood control. The masses who live in floodplain sacrificed much for protecting security of people who live in Huanghuaihai plain. Because of sediments of the Yellow River, the floodplain in the lower reach of the Yellow River can not be closed like other rivers. Since 1970s of last century, government has established beneficial policy for masses in floodplain that is for free the public commissariat tax. However, this policy is not yet adaptable due to national agriculture free tax today.

In order to be advantageous for tackling the contradiction between flood control and masses' living in floodplain, meanwhile, to realize the long term security of Yellow River harness and be beneficial to get rid of badly off situations of masses in floodplain, masses living in floodplain should enjoy the national compensations policy for flood detaining area as early as possible.

Floodplain in the lower reach of the Yellow River is an important part of flood control and is a habitant area of people who live in floodplain. It possesses character of flood detained area. Water and sand regulations renders main channel to keep nearly discharge of 4,000 m<sup>3</sup>/s. River training projects make the main channel steadily. Optimization of reservoir regulations can reduce odds of overflow of flood plain under little or middle discharge and the overflowing probability may reach once in three to five years. Through the safety construction of floodplain, people near bank would migrate from inside to outside floodplain. Other villages will be gathered to construct town. And village protecting platform will be set up according to standard of once in twenty years. In addition, contradiction will be settle down between floodplain people residing and flood controlling through implementing compensation policy. Harmonious society of floodplain will be improved.

# Overland Flow Erosion Capacity

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**Abstract:** Soil erosion caused by water flow is a complex problem. Both empirical and physically based approaches were used for the estimation of surface erosion rates. Their applications are mainly limited to experimental areas or laboratory studies. The maximum sediment concentration overland flow can carry is not considered in most of the existing surface erosion models. The lack of erosion capacity limitation may cause over estimations of sediment concentration. A correlation analysis is used in this study to determine significant factors that impact surface erosion capacity. A bounded regression formula is used to reflect the limits that sediment concentration cannot be less than zero nor greater than a maximum value. The coefficients used in the model are calibrated using published laboratory data. The computed results agree with laboratory data very well. A one dimensional overland flow diffusion wave model is used in conjunction with the developed soil erosion equation to simulate field experimental results (Barfield et al., 1983). This study concludes that the non – linear regression method using unit stream power as the dominate factor performs well for the analysis of overland flow erosion capacity.

**Key words:** overland flow, erosion capacity

## 1 Introduction

Soil erosion is a two – phase process consisting of detachment and transport of individual soil particles from soil mass. Rain – splash and running water are two of the most important detachment agents to remove soil particles from soil surface. Detached soil particles are transported by running water. When sufficient energy is no longer available to transport soil particles, a third phase, deposition, occurs.

Surface soil erosion is a complicated problem affected by micro – topography, land cover, surface materials, flow characteristics, boundary conditions, etc. Numerical models are often used to predict the surface soil erosion processes in a watershed. Each calculating element in a numerical model contains information of bed material, flow type, and flow characteristics. It is difficult to have an analytic solution for the prediction of soil erosion processes. Therefore, empirical approaches using physically based parameters should be used to estimate surface erosion rate.

Due to the large number of variables involved for complicated hydrologic and hydraulic problems, the power function type of models are often used to obtain statistical solutions. Bed load sediment transport formulas in a power function type of equations were recommended by Foster and Meyer (1972) and Gilley, et al. (1985) for the estimation of surface erosion rate. This type of formula can be expressed as

$$q_s = A \cdot \Omega_e^B \quad (1)$$

where,  $q_s$  is sediment discharge per unit width,  $A$  and  $B$  are parameters related to flow and sediment conditions, and  $\Omega_e$  is effective dominant variable. Because flow discharge and bed slope are traditionally considered as significant factors and can be directly measured in a laboratory, a commonly used empirical erosion equations is

$$q_s = kq^\alpha S^\beta \quad (2)$$

where,  $\alpha$ ,  $k$  and  $\beta$  = coefficients, and  $q$  = unit discharge. The values of  $1.2 < \alpha < 1.9$  and  $1.4 < \beta < 2.4$  were recommended by Julien and Simons (1985). The values of  $1.0 < \alpha < 1.8$  and  $0.9 < \beta < 1.8$  were recommended by Prosser and Rustomji (2000). For overland flow, sediment transport

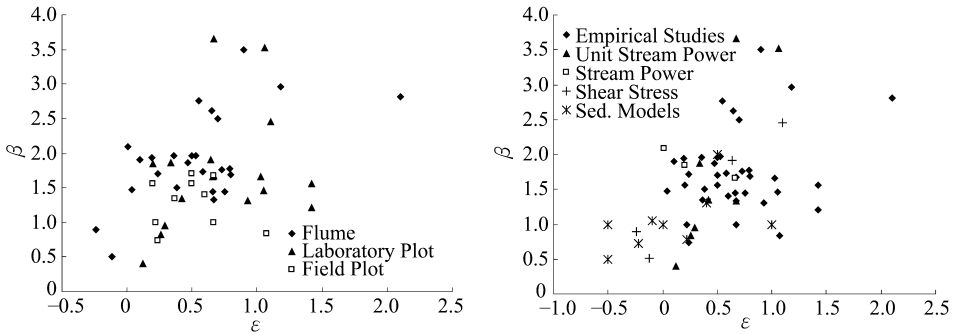
rate is defined as the amount of soil particles carried by running water and expressed by a production of flow discharge and sediment concentration, i. e.

$$q_s = q \cdot C_s \quad (3)$$

Eq. (3) can be re-written as

$$C_s = kS^\beta q^\varepsilon \quad (4)$$

where,  $C_s = q_s/q$ , and  $\varepsilon = \alpha - 1$ . Sediment concentration is proportional to slope and flow discharge, and the coefficients  $\beta$  and  $\varepsilon$  are greater than zero. This study calibrated the values of power coefficients of existing overland flow sediment transport equations from 1947 to 1999. Fig. 1 shows that the coefficients are not constant. They vary with different data sources and variables used. We also found that some equations have negative power coefficients for unit flow discharge. This means that the sediment concentration is inversely proportional to unit discharge, which is not reasonable. This suggests that coefficients of Eq. (4) should be revised to reflect the variation of flow conditions.



**Fig. 1 Exponents of the sediment transport equations for overland flow**

The maximum saturated sand concentration, with voids among particles, is 1,922,000 mg/L. Using traditional formula, Eq. (4), may over estimate sediment concentration at high flow rates condition. For example, two overland flow sediment transport equations are expressed as

Kilinc's (1972)

$$C_{mgl} = 1,986,289,351 \times q^{1.035} S^{1.664} \quad (5)$$

Guy et al. (1987)

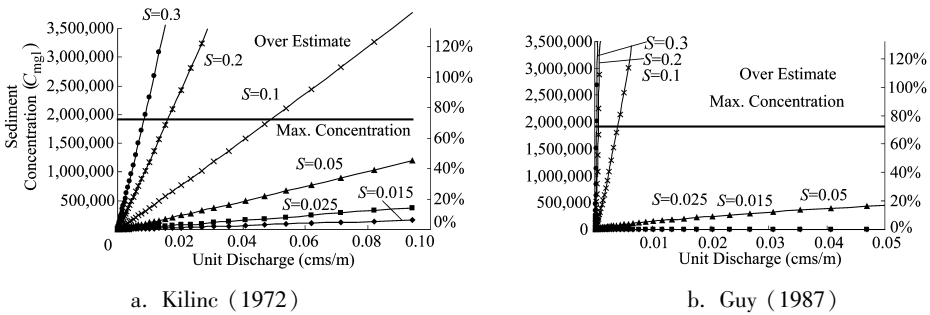
$$C_{mgl} = 1.13 \times 10^{18} \times q^{2.986} S^{8.835 + 0.767 \ln(q)} \quad (6)$$

where,  $C_{mgl}$  = sediment concentration in mg/L. Fig. 2 shows that Eq. (5) and Eq. (6) can over estimate sediment concentration exceeding the maximum concentration limit. Therefore, the exponent for flow rate in a sediment transport equation should be revised. A rational sediment transport equation for overland flow erosion should consider the maximum sediment concentration limit.

Overland flow characteristics are different from channel flow (Govers, 1992). The traditional forms of bed load transport equations need to be revised for overland flow soil erosion considering the limits of sediment concentration.

## 2 Overland flow characteristics and physical parameters

During a rainfall event, rain drops hit ground surface and detach surface particles from soil mass. Soil particles may be deposited on ground after detachment by rain drop because no excess surface runoff can transport those particles downstream. For shallow sheet flows, rain drops may disturb overland flow and change the critical condition of particle entrainment. Once particles are detached from surface, surface flow may carry particles downstream. In this case, flow and raindrops



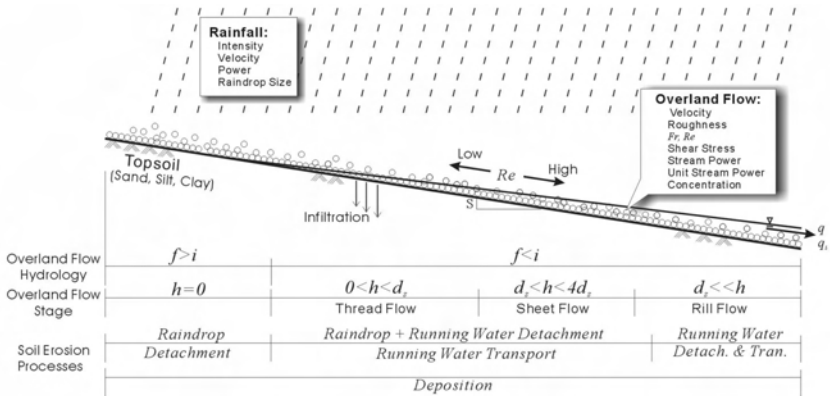
a. Kilinc (1972)

b. Guy (1987)

**Fig. 2 Overestimating using Kilinc's and Guy's overland flow sediment transport equations**

are dominant parameters. As flow depth increases in the downstream direction, rain drop impact on erosion decreases, and surface flow dominates particle detachment and transport processes.

According to previous studies, relevant variables for soil erosion can be grouped into rainfall impact, flow characteristics, and bed conditions. Fig. 3 illustrates surface soil erosion process on bare soil surface. Physical parameters representing each group are described herein.



**Fig. 3 Particle detachment, transport and deposition on bare soil surface**

## 2.1 Rainfall impact

Influence of rainfall can be represented by rainfall intensity  $i$ , ratio of rainfall intensity to flow depth  $i/h$  (Ferro, 1998), rainfall velocity  $V_i$ , rainfall power  $P_i$ , or ratio of rainfall intensity to flow velocity  $i/V$ . Rainfall velocity and rainfall power can be expressed as

$$V_i = 6.6i^{0.07} \quad (\text{Schmidt, 1993}) \quad (7)$$

$$P_i = \frac{\rho i V_i^2 \cos\theta}{2} \quad (\text{Gabet and Dunne, 2003}) \quad (8)$$

where,  $\rho$  = density of water ( $1,000 \text{ kg/m}^3$ ),  $\theta$  = hill slope angle, and  $i/V$  = a dimensionless ratio between rainfall intensity and flow velocity.

## 2.2 Flow characteristics

Based on basic assumptions of most sediment transport equations (Graf, 1971; Yang, 1972,

1973, 1996; Foster and Meyer, 1972, 1975), flow velocity  $V$ , stream power per unit width  $qS$ , unit stream power  $VS$ , or shear stress  $\tau$  are considered as dominate variables. In addition to the above variables, energy slope  $S_e$ , unit discharge  $q$ , flow depth  $h$ , Reynolds numbers  $Re$  and Froude number  $Fr$  are some of the physical parameters used by many for the estimation of erosion and sediment transport rate. Reynolds number is the ratio of inertia force to viscous force. Froude number is the ratio of inertia force to gravity force. They are defined as

Froude number is

$$Fr = \frac{V}{\sqrt{gh}} \quad (9)$$

where,  $v$  is kinematic viscosity of water,  $h$  is flow depth, and  $g$  = gravitational acceleration.

Flow Reynolds number is

$$Re = \frac{Vh}{v} \quad (10)$$

Grain shear Reynolds number is

$$Re_* = \frac{u_* d_s}{v} \quad (11)$$

where,  $d_s$  = sediment diameter,  $v$  kinematic viscosity, and shear stress velocity  $u_*$  is defined as

$$u_* = \sqrt{ghS} \quad (12)$$

Particle Reynolds number is

$$Re_p = \frac{\omega \cdot d_s}{v} \quad (13)$$

The fall velocity of sand particles can be calculated by (Julien 1994)

$$\omega = \frac{8v}{d_s} [(1 + 0.013,9d_s^3)^{0.5} - 1] \quad (14)$$

where, the dimensionless particle diameter  $d_*$  is defined as

$$d_* = d_s \left[ \frac{(G-1)g}{v^2} \right]^{1/3} \quad (15)$$

where,  $G$  = specific gravity of sediment = 2.65.

Flow is turbulent if  $Re > 2,000$ ,  $Re_* > 70$  or  $Re_p > 1$ .

### 2.3 Bed condition

Bed roughness and particle entrainment can dissipate flow energy and decrease the sediment transport capacity. On a bare soil surface, micro – topography has a significant effect on flow resistance and flow erosion rate. Bed particle size  $d_s$  and relative submergence  $h/d_s$  or relative roughness  $d_s/h$  are used to express the bed condition in this study. Yang (1979) suggested that incipient motion criteria can be disregarded when sediment concentration is greater than 100 ppm by weight which is much less than that of overland flow. Therefore, overland flow critical condition for particle entrainment can be ignored in this study.

Correlation analyses will be applied in the following sections to determine the significance of parameters using laboratory data.

### 3 Existing data

In order to increase the statistical significance of a regression analysis, a large number of samples are needed. Laboratory data by Kilinc (1972), Aziz and Scott (1989), and Guy and Dickinson (1990) are used to determine the significance of physical parameters for the development of regression equations to estimate surface soil erosion rate. A total of 158 sets of data including 42 set of data taken from simulated rainfalls are used in this paper. The ranges of each parameter are summarized in Table 1. Mean particle size  $d_{50}$  is used to represent particle size  $d_s$ , and flume slope or soil surface slope  $S$  is used as energy slope of overland flow.

**Table 1 Summary of laboratory data of overland flow sediment transport experiments**

Parameter	Concentration $C_{mgl}$	$d_{50}$ (mm)	Slope (m/m)	Rainfall Intensity (mm/h)	Unit flow Discharge ( $m^2/(s \cdot m)$ )	Flow Depth $h$ (mm)
Max	612,504	1.0	0.4	223	0.004,732	11.6
Min	959	0.2	0.02	32	9.07E-06	0.2
Parameter	Flow Velocity $V$ (m/s)	$VS$ (m/s)	$qS$ (cms/m)	$\tau$ ( $N/m^2$ )	$Re$	$Re^*$
Max	0.706	125.73	0.463,7	0.866	54.806	94.5
Min	0.019	0.38	0.000,2	0.007	0.002	1.9
Parameter	$Fr$	$h/d_s$ Relative Submergence	Rain Fall Velocity $V_i$ (m/s)	Rainfall Power $P_i$ (kg/s)	$i/V$	$i/h$ (1/s)
Max	4.61	29.95	3.35	0.35	0.001,3	0.151
Min	0.27	0.99	2.92	0.035	7.16E-05	0.018

Besides the use of above laboratory data for regression analyses, field experimental data collected by Barfield et al. (1983) are used to validate the developed regression equations. Field erosion experiments were done on an area of 4.6 m by 22.1 m on a 9% slope. The observed hydrograph and sediment graph of seven experiment runs will be used to compare with simulated results from this study. The soils in the field were wet and tilled topsoil. Table 2 summaries the field test conditions.

**Table 2 Summary of field experiment runs (Barfield etc. , 1983)**

Run No.	Bed Material	Rainfall Intensity (mm/h)	Rainfall Duration (min)	$d_{50}$ (mm)	Soil Yield Per Unit Width (g/m)	Soil Erodibility Factor, $K$ (tons/acre)
P33231	Tilled & Wet Topsoil	66		0.06	5,577.78	0.437
P33131		61			4,203.67	0.388
P32131		66			8,829.77	0.527
P32231	Tilled & Wet Subsoil	66	30	0.04	4,846.85	0.371
P32331		66			4,342.51	0.256
P31131		61			1,011.25	0.148
P31231	Tilled & Wet Shale	61		0.05	893.04	0.126

#### 4 Bed load transportation equations and dominant physical parameters based on power function

The mechanism of overland flow sediment transportation can be treated as bed load transportation. Eq. (1) is used to estimate overland flow erosion capacity. Most of the previous studies suggested the use of flow rate, flow velocity, shear stress, stream power, unit stream power, or dimensionless unit stream power as a dominant factor for sediment transport. Therefore, the basic forms of overland flow erosion equation can be expressed as

$$q_s = A \cdot V^B \quad (16)$$

$$q_s = A \cdot q^B = A \cdot (V \cdot h)^B \quad (17)$$

$$q_s = A \cdot \tau^B = A \cdot (\gamma \cdot VS)^B, \text{ or } q_s \propto A \cdot (h \cdot S)^B \quad (18)$$

$$q_s = A \cdot (\gamma \cdot VS)^B, \text{ or } q_s \propto A \cdot (VS)^B \quad (19)$$



$$q_s = A \cdot \left( \gamma \cdot \frac{VS}{\omega} \right)^B, \text{ or } q_s \propto A \cdot \left( \frac{VS}{\omega} \right)^B \quad (20)$$

$$q_s = A \cdot (\tau V)^B = A \cdot (\gamma \cdot h \cdot S \cdot V)^B, \text{ or } q_s \propto A \cdot (h \cdot S \cdot V)^B \quad (21)$$

$$q_s = A \cdot (\gamma \cdot qS)^B = A \cdot (\gamma \cdot h \cdot S \cdot V)^B, \text{ or } q_s \propto A \cdot (h \cdot S \cdot V)^B \quad (22)$$

where,  $\gamma$  specific weight of water which is treated as a constant in this study,  $VS$  = unit stream power per unit weight of water,  $VS/\omega$  = dimensionless unit stream power per unit weight of water,  $\tau V$  = stream power per unit bed area,  $qS$  = stream power per unit width. Eqs. (21) and (22) show that  $\tau V$  and  $qS$  have the same dimension for overland flow.

In this study, 158 sets of laboratory data are used to test the goodness of fit of six regression equations. If data collected during rain falls are excluded, only 116 sets of data of surface flow are used to make simple regression analysis. Sediment concentration is treated as a dependent variable. The results and ranking based on their correlation coefficient  $R^2$  are

$$C_{\text{mgl}} = 4,684,972.4 (VS)^{1.217}, R^2 = 0.879 \quad (23)$$

$$C_{\text{mgl}} = 19,709,844 (qS)^{0.68}, R^2 = 0.714 \quad (24)$$

$$C_{\text{mgl}} = 161,366 (\tau)^{1.11}, R^2 = 0.680 \quad (25)$$

$$C_{\text{mgl}} = 172,856.6 (V)^{1.519}, R^2 = 0.667 \quad (26)$$

$$C_{\text{mgl}} = 130,081 \left( \frac{VS}{\omega} \right)^{1.022}, R^2 = 0.661 \quad (27)$$

$$C_{\text{mgl}} = 1,243,153 (q)^{0.554}, R^2 = 0.458 \quad (28)$$

The above results show that Eq. (23) has the highest correlation coefficient. Unit stream power is the most significant variable for surface erosion. Unit discharge does not have strong correlation with sediment concentration from regression analysis, although it can be directly measured from experiments. The variation of coefficients may depend on flow, soil surface and rainfall conditions. Correlation analyses are performed to determine the most significant variables. The resulting correlations are shown in Table 3. The unit stream power,  $\Phi = VS$ , has the highest correlation coefficient of 0.94 with sediment concentration  $C_s$ . The least significant variable is unit discharge with a correlation coefficient of 0.27. This contradicts the traditional believe that unit discharge is a significant factor for overland flow erosion. Although the fall velocity  $\omega$  varies as a function of water temperature and particle size, due to the lake of temperature measurement  $\omega$  is treated as a constant in this study. This may be the reason why  $\Phi$  has higher correlation with  $C_{\text{mgl}}$  than  $\Phi/\omega$ .

**Table 3 Correlation table of traditional dominant variables**

Correlations	$C_s$	$q$	$V$	$\Phi$	$\Phi/\omega$	$\Psi$	$\tau$
$C_s$	1	0.27	0.59	0.94	0.82	0.68	0.63
$q$	0.27	1	0.83	0.33	-0.03	0.76	0.73
$V$	0.59	0.83	1	0.68	0.38	0.82	0.74
$\Phi$	0.94	0.33	0.68	1	0.79	0.76	0.69
$\Phi/\omega$	0.82	-0.03	0.38	0.79	1	0.29	0.17
$\Psi$	0.68	0.76	0.82	0.76	0.29	1	0.95
$\tau$	0.63	0.73	0.74	0.69	0.17	0.95	1

Note: Stream power per. unit width  $\Psi = qS$ .

## 5 Correlation and regression analysis

A correlation analysis is used to determine the significance of physical parameters. Excluding the data with rainfall events, the factors used in correlation analysis are sediment concentration  $C_s$ ,

particle size  $d_s$ , bed slope  $S$ , unit discharge  $q$ , flow depth  $h$ , flow velocity  $V$ , particle fall velocity  $\omega$ , flow Reynolds number  $Re$ , grain shear Reynolds number  $Re^*$ , particle Reynolds number  $Re_p$ , Froude number  $Fr$ , and relative submergence  $h/d_s$ .

Table 4 shows the correlation coefficients of different parameters. It is apparent that Froude number has a higher correlation than Reynolds numbers because overland flow is a gravity flow. The correlation coefficient between slope and velocity is only  $-0.04$  which is very weak. This means that slope and flow velocity are independent from each other. The correlations of particle size and relative submergence with sediment concentration are weak. This means that particle roughness is not an important factor, or the weak correlation is caused by a narrow range of particle size used in the analysis.

**Table 4 Correlation table of physically effective factors**

	$C_s$	$d_s$	$S$	$q$	$h$	$V$	$\omega$	$Re$	$Re^*$	$Re_p$	$Fr$	$h/d_s$
$C_s$	1	0.001	0.59	0.27	0.05	0.59	0.02	0.12	-0.01	0.26	0.70	0.13
$d_s$	0.001	1	-0.16	0.44	0.65	0.22	0.99	0.47	0.99	0.93	-0.29	-0.20
$S$	0.59	-0.16	1	-0.28	-0.44	-0.04	-0.19	-0.31	-0.14	-0.01	0.52	-0.39
$q$	0.27	0.44	-0.28	1	0.91	0.83	0.50	0.95	0.40	0.56	0.08	0.63
$h$	0.05	0.65	-0.44	0.91	1	0.65	0.69	0.91	0.61	0.66	-0.15	0.55
$V$	0.59	0.22	-0.04	0.83	0.65	1	0.30	0.64	0.16	0.39	0.52	0.62
$\omega$	0.02	0.99	-0.19	0.50	0.69	0.30	1	0.51	0.97	0.93	-0.26	-0.15
$Re$	0.12	0.47	-0.31	0.95	0.91	0.64	0.51	1	0.45	0.56	-0.05	0.54
$Re^*$	-0.01	0.99	-0.14	0.40	0.61	0.16	0.97	0.45	1	0.93	-0.31	-0.23
$Re_p$	0.26	0.93	-0.01	0.56	0.66	0.39	0.93	0.56	0.93	1	-0.14	-0.11
$Fr$	0.70	-0.29	0.52	0.08	-0.15	0.52	-0.26	-0.05	-0.31	-0.14	1	0.13
$h/d_s$	0.13	-0.20	-0.39	0.63	0.55	0.62	-0.15	0.54	-0.23	-0.11	0.13	1

Rainfall intensity  $i$ , raindrop velocity  $V_i$ , rainfall power  $P_i$ , the ratio of rainfall intensity to flow velocity  $i/V$ , and the ratio of rainfall intensity to flow depth  $i/h$ , are used to determine the importance of factors associated with rainfall drops. The comparison is summarized in Table 5. Ratio of rainfall intensity  $i$  to flow velocity  $V$  has the highest correlation coefficient of  $-0.43$  with rainfall impact on sediment concentration of surface erosion rate.

Statistical analyses of data shown in Table 4 and Table 5 suggest that parameters in Eq. (29) should be used to develop an overland flow sediment transport equations.

$$C_{mgl} = f(\Phi, Fr, V, S, i/V) \quad (29)$$

Bounded Exponential Regression Formula

One of the primary objectives of this study is to develop an overland flow sediment transport equation with the consideration of the minimum and maximum concentration limits which are zero mg/L and 1,922,000 mg/L, respectively, for sand particles. A bounded exponential regression formula, Weibull Function (Weibull, 1951), can present bounded limits. The general form of Weibull Function is

$$Y = 1 - e^{-X} \quad (30)$$

where,  $Y$  and  $X$  = variables. Then

$$Y \rightarrow 1 \text{ when } X \rightarrow \infty \quad (31)$$

and

$$Y \rightarrow 0 \text{ when } X \rightarrow 0 \quad (32)$$

In this study, measured sediment concentration  $C_{mgl}$ , is the dependent variable  $Y$ , and the power function of the dominant variable  $a \cdot \Omega^b$  is the independent variable  $X$ . A Weibull Function based regression formula is used to estimate the sediment transport capacity of overland flow and is expressed as

**Table 5 Correlation table of physical factors regarding rainfall impact**

Correlations	$C_s$	$i$	$V_i$	$P_i$	$i/V$	$i/h$
$C_s$	1	-0.04	0.06	-0.07	-0.43	0.04
$i$	-0.04	1	0.97	1.00	0.73	0.81
$V_i$	0.06	0.97	1	0.96	0.64	0.77
$P_i$	-0.07	1.00	0.96	1	0.75	0.80
$i/V$	-0.43	0.73	0.64	0.75	1	0.52
$i/h$	0.04	0.81	0.77	0.80	0.52	1

$$C_{mgl} = C_{max} \cdot (1 - e^{-a \cdot \Omega^b}) \quad (33)$$

where,  $a$  and  $b$  = coefficients, and  $C_{max}$  = maximum allowable concentration. For saturated sand particles with voids among particles,  $C_{max} = 1,922,000$  mg/L. This formula is a nonlinear function of dominate variable  $\Omega$ .

In this study, unit stream power  $\Phi$  is shown as the most significant dominant variable. Eq. (33) can be written as

$$C_{mgl} = 1,922,000 \cdot (1 - e^{-M \cdot \Phi^N}) \quad (34)$$

where,  $M$  and  $N$  = functions of physical parameters. Gilbert (1914) showed that  $M$  always increases linearly with increasing value of  $N$ . Hence,  $M$  and  $N$  can be expressed as

$$M = m_1 \cdot S + m_2 \cdot V + m_3 \cdot Fr + m_4 \quad (35)$$

$$N = n_1 \cdot S + n_2 \cdot V + n_3 \cdot Fr + n_4 \quad (36)$$

where,  $m_i$  and  $n_i$  = coefficients.

Non-linear regression analysis is used to determine the coefficients of proposed soil erosion formulas, Eq. (35) and (36). The regression equation obtained by using surface flow data excluding those with rainfall data is

$$C_{mgl} = 1,922,000 \cdot (1 - e^{-M \cdot \Phi^N}), C_{mgl} = 0 \text{ if } C_{mgl} \leq 0 \quad (37)$$

where

$$M = -0.654 \cdot S - 3.848 \cdot V + 0.227 \cdot Fr + 2.657 \quad (38)$$

$$N = -1.692 \cdot S - 1.170 \cdot V + 0.071 \cdot Fr + 1.532 \quad (39)$$

with  $R^2 = 0.911$ .

For all 158 sets of data, including those collected during rainfall, we obtain the equation

$$C_{mgl} = 1,922,000 \cdot (1 - e^{-(M \cdot \Phi^N) \left(1 + a \left(\frac{i}{V}\right)^b\right)}), C_{mgl} = 0 \text{ if } C_{mgl} \leq 0 \quad (40)$$

where

$$M = -0.654 \cdot S - 3.848 \cdot V + 0.227 \cdot Fr + 0.657 \quad (41)$$

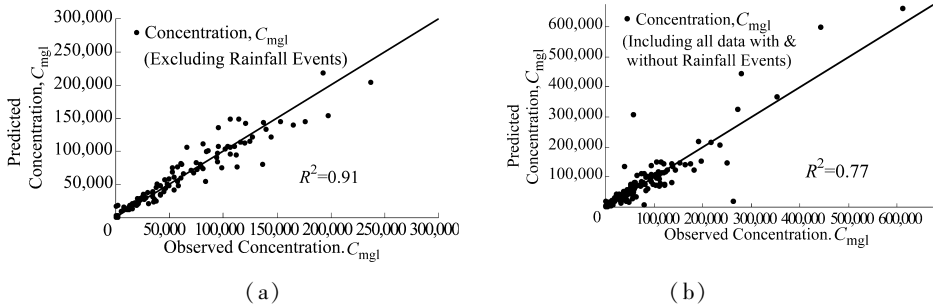
$$N = -1.692 \cdot S - 1.170 \cdot V + 0.071 \cdot Fr + 1.532 \quad (42)$$

$$a = 18,801.996 \quad (43)$$

$$b = 1.716 \quad (44)$$

with  $R^2 = 0.769$ .

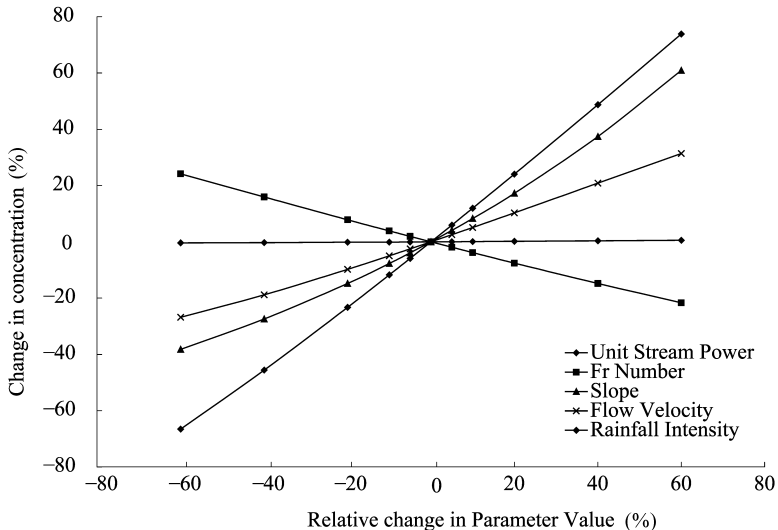
Both regression equations have high  $R^2$  values. A regression equation with  $R^2$  greater than 0.75 is considered a good regression equation. Fig. 4 shows the agreement between predicted and observed sediment concentrations. A comparison between Fig. 4(a) and 4(b) shows that the correlation is higher for these data excluding those taken during rainfall events. Rainfall events can complicate the relationship between surface erosion rate and unit stream power.



**Fig. 4** Agreements between the revised non – linear regression equations and data

## 6 Sensitivity analysis

Sensitivity analyses of the developed model are performed by changing the values of each input variable to a range from  $-60\%$  to  $60\%$ . The variation of predicted concentration versus input variables are plotted in Fig. 5. The analysis shows that unit stream power has the steepest slope on the plot and is the most sensitive variable in the model with respect to sediment concentration. The sensitivity analyses results support the idea that the unit stream power is the dominant factor for surface erosion studies. Flow velocity, slope, and Froude number are other sensitive variables. Rainfall intensity is less sensitive than others. This analysis shows that gravity is the significant driving force for overland flow, and the unit stream power dominates sediment concentration.



**Fig. 5** Plot of sensitivity analysis

## 7 Practical application and dimensionless soil erodibility factor $K'$

For bare soil surface, soil erosion or yield can be expressed as

$$\text{Soil Yield} = f(\text{Erosivity, Erodibility}) \quad (45)$$

Erosivity is the soil loss potential caused by overland flow and rain drops detachment. It is a function of overland flow characteristics, bed conditions and rainfall intensity. Erodibility is the

inherent susceptibility of soil particles or aggregates to become detached or transported by erosive agents such as rainfall and surface runoff. Erodibility is dominated by soil properties, land covers and topography. Flow erosivity and sand erodibility are included in the regression equation development. For practical purposes, a representative erodibility is needed for the regression equation. The most commonly used erodibility factor is the  $K$  (tons/acre) value in the Universal Soil Loss Equation (Wischmeier and Smith, 1962, 1965, 1978). The representative erodibility  $K_s$  of the regression equation developed in this study is determined from field data of Barfield et al. (1983). The  $K_s$  value is 0.038 tons/acre. In order to apply the equations developed from this study, the following dimensionless soil erodibility factor  $K'$  is used

$$K' = \frac{K}{K_s} = \frac{K}{0.038} \quad (46)$$

For bare soil surface, an equation for the computation of overland sediment discharge can be expressed as

$$q_s = q \cdot C_{mgl} \quad (47)$$

where

$$C_{mgl} = K' \cdot 1,922,000 \cdot (1 - e^{-(M \cdot \Phi^N)(1 + a(\frac{i}{V})^b)}) \quad (48)$$

$$\Phi = VS \quad (49)$$

$$M = -0.654S - 3.848V + 0.227Fr + 2.657 \quad (50)$$

$$N = -1.692S - 1.170V + 0.071Fr + 1.532 \quad (51)$$

$$a = 18,801.996 \quad (52)$$

$$b = 1.716 \quad (53)$$

$$K' = \frac{K}{0.038} \quad (54)$$

## 8 Model test using one dimensional overland flow erosion simulation

Experimental field data of Barfield et al. (1983), as shown in Table 2, are used to examine equations developed in this paper. A one dimensional (1D) diffusion wave routing model is developed to simulate hydrologic condition and predict soil erosion or yield. The 1D diffusion wave equation of overland flow is a partial differential equation

$$\frac{\partial h}{\partial t} + c \frac{\partial h}{\partial x} - D_d \frac{\partial^2 h}{\partial x^2} = (i - f) \quad (55)$$

where,  $c = \eta V$ ;  $D_d = \frac{Vh}{2S_e}$ ;  $t$  = time,  $f$  = soil infiltration rate, and  $x$  = distance. If Manning equation is used to represent flow resistance, then,  $\eta = 5/3$  and

$$c = \frac{5}{3}V \quad (56)$$

where,  $V = \frac{1}{n}h^{2/3}\sqrt{S_e} = \frac{1}{n}h^{2/3}\sqrt{S - \frac{\partial y}{\partial x}}$ , and  $n$  = Manning roughness coefficient. The numerical solution of 1 - D diffusion wave equation can be obtained by using MacCormack (1971) scheme.

In the MacCormack scheme, the derivative operator is the average of the forward and backward operators such that

$$h = \frac{h^* + h^{**}}{2} \quad (57)$$

where,  $h$  = predicted flow depth, and  $h^*$ ,  $h^{**}$  = one - sided forward and backward differences, respectively. Eq. (55) can be approximated by a forward difference in time and in space to give predictor step

$$\frac{h_n^* - h_n^j}{\Delta t} + c \frac{h_{n+1}^j - h_n^j}{\Delta x} - (D_d + D_{num}) \frac{h_{n+1}^j - 2h_n^j + h_{n-1}^j}{\Delta x^2} = (i - f)_n \quad (58)$$

$$\Rightarrow h_n^* = h_n^j - \frac{c\Delta t}{\Delta x}(h_{n+1}^j - h_n^j) + (D_d + D_{num}) \frac{\Delta t}{\Delta x^2}(h_{n+1}^j - 2h_n^j + h_{n-1}^j) + (i-f)_n^j \Delta t \quad (59)$$

where,  $\Delta t$  = time step,  $\Delta x$  = distance step,  $j$  = simulation time,  $n$  = simulation location,  $D_{num}$  = the truncation error of the advection scheme includes a numerical diffusion term (Julien, 2002), and

$$D_d + D_{num} = \frac{Vh}{2S_c} + \left( \frac{-c^2 \Delta t}{2} + \frac{c\Delta x}{2} \right) \quad (60)$$

Similarly, Eq. (55) can be approximated by a backward difference in time and in space to give the corrector step

$$\frac{h_n^{**} - h_n^*}{\Delta t} + c \frac{h_n^* - h_{n-1}^*}{\Delta x} - (D_d + D_{num}) \frac{h_{n+1}^* - 2h_n^* + h_{n-1}^*}{\Delta x^2} = (i-f)_n^* \quad (61)$$

$$\Rightarrow h_n^{**} = h_n^* - \frac{c\Delta t}{\Delta x}(h_n^* - h_{n-1}^*) + (D_d + D_{num}) \frac{\Delta t}{\Delta x^2}(h_{n+1}^* - 2h_n^* + h_{n-1}^*) + (i-f)_n^* \Delta t \quad (62)$$

The Courant number,  $C_c = \frac{c\Delta t}{\Delta x} = \frac{5}{3} V \frac{\Delta t}{\Delta x}$ , is used to check numerical scheme stability.

MacCormack scheme is stable if  $C_c \leq 1$ .

Field experimental runs are used to test the 1D diffusion overland flow model and the developed soil erosion equations, from Eq. (47) to Eq. (54). The suggested Manning roughness and average infiltration rate of numerical simulation are presented in Table 6.

Examples of simulation results and observed data are plotted in Fig. 6 and Fig. 7 with good agreements between predicted value and observed data. In the 1D numerical model, the maximum  $C_c$  values from simulated runs are within 0.37 to 0.74. This means that the routing model is stable because  $C_c \leq 1$ . The 1D overland flow scheme and the developed soil erosion equation can represent soil erosion processes of overland flow very well.

**Table 6 Suggest Manning  $n$  and average infiltration rate**

Run No.	Manning $n$	Average infiltration rate, $f$ (mm/h)	$K'$	$C_c$	$i_c$ (in)
P33231	0.13	10.5	11.50	0.49	1.06
P33131	0.10	4.5	10.21	0.58	1.09
P32131	0.10	4.5	13.87	0.60	1.19
P32231	0.07	7.1	9.76	0.74	1.14
P32331	0.07	7.1	6.74	0.74	1.14
P31131	0.10	2.0	3.89	0.59	1.15
P31231	0.20	8.5	3.32	0.37	0.99

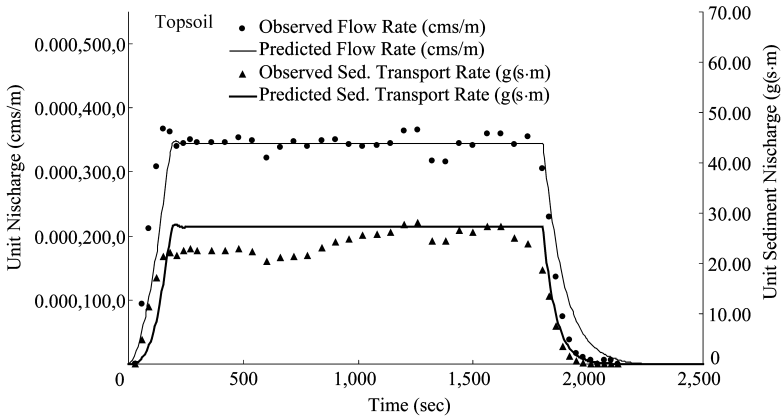
## 9 Model validation

In this study, the following efficiency coefficient proposed by Nash and Sutcliffe (1970) is used as an alternative to the correlation coefficient to determine the performance of a model:

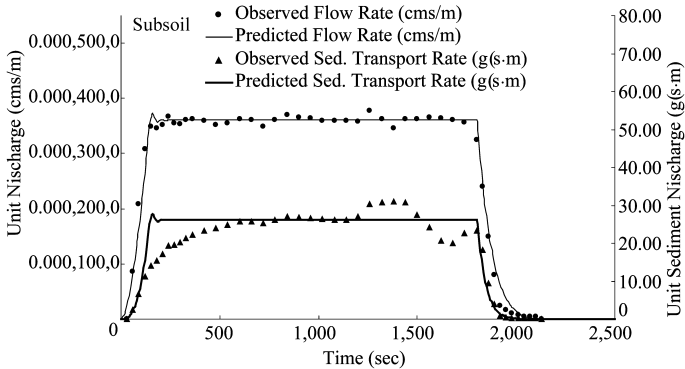
$$CE = \frac{\sum (X_{obs} - X_{mean})^2 - \sum (x_{pred} - X_{obs})^2}{\sum (X_{obs} - X_{mean})^2} \quad (63)$$

where,  $X_{obs}$  = the observed value,  $X_{mean}$  = the mean of a set of observed values and  $X_{pred}$  = the predicted value. Generally speaking, a  $CE$  value greater than 0.5 is considered satisfactory (Quinton 1997).

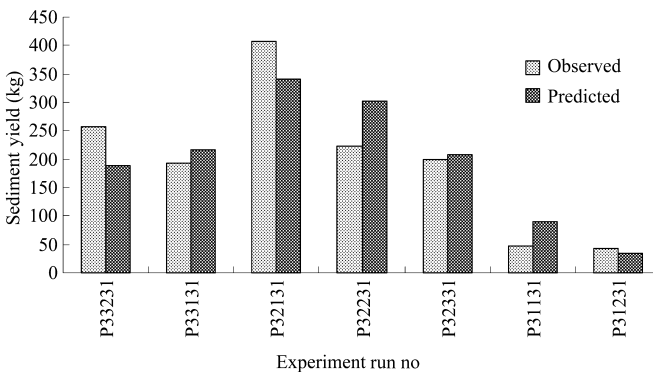
Fig. 8 shows the comparison between observed and predicted results. Based on the definition of the  $CE$  value, Eq. (63), Table 7 summarizes the observed and predicted values used in the computation of  $CE$ . The result of model validation calculation has a  $CE$  value of 0.814 as shown in



**Fig. 6 Comparison between predicted results and observed data for Run No. P33131**



**Fig. 7 Comparison between predicted results and observed data for Run No. P32331**



**Fig. 8 Sediment yield comparison between observed data and predicted values**

Eq. (64).

**Table 7 Calculation table of the model validation**

Run No	Sediment Yield (kg)		$(X_{obs} - X_{mean})^2$	$(X_{pred} - X_{obs})^2$
	Observed	Predicted		
P33231	257	188	3,739	4,647
P33131	193	216	4	508
P32131	406	341	44,481	4,248
P32231	223	303	758	6,340
P32331	200	209	19	82
P31131	47	89	21,985	1,750
P31231	42	34	23,587	58
Mean	195.43	Sum	94,573	17,633

$$CE = \frac{94,573 - 17,633}{94,573} = 0.814 \quad (64)$$

## 10 Conclusions

Correlation and regression analyses showed that unit stream power has the highest correlation among all dominant variables for the determination of surface erosion rate. Flow velocity, slope, and Froude number are other important factors for overland flow sediment transport. Slope and flow velocity of overland flows are not closely related to each other because the correlation between them is very weak. The correlation analyses also show that overland flow is dominated by gravity force, and particle size is not an important factor which means that relative roughness is not important. It is possible that particle size range of eroded soil used in this study is too narrow to show its effect.

A revised Weibull Function based regression formula is used to develop the overland flow sediment transport equations. The equations thus developed can predict sediment transport rate with varying flow conditions and rainfall impact. They also include the considerations of sediment concentration limits. The predicted results agree with observed data very well. Sensitivity analysis results show that unit stream power is the most important parameter for the estimation of surface erosion rate. This is consistent with the use of unit stream power in a sediment transport equation for rivers.

The soil erosion equation developed in this study can be applied to field conditions using a dimensionless soil erodibility factor  $K'$ . A 1D diffusion overland flow routing model was developed using the MacCormack scheme. Seven experimental runs of field data (Barfield et al, 1983) agree with simulated results using the soil erosion equation developed in this study and the 1D diffusion wave routing. A high efficiency coefficient of  $CE = 0.814$  for model validation in this study confirms that the model is satisfactory.

The unit stream power method has been shown to be a powerful tool for the analysis of sediment transport in alluvial channels. Laboratory and field data used in this study have shown that the surface erosion equations based on unit stream power as their dominant variable have very high reliability for the determination of erosion rate of overland flow.

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# Preliminary Study on “Maintaining the Healthy Life of the Yellow River” Production System

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**Abstract:** This paper focus on the production system of the “maintaining the healthy life of the Yellow River” theoretical frame and its composition. On the basis of theoretical system research results, for the purpose of realizing the ultimate goal, proceeding with the severe survival crisis encountered by the Yellow River, major ways, measures, technical means and guarantee measures such as water increase, sediment reduction, water and sediment regulation, lower river course control, aquatic environment and river ecological protection have been proposed around the existing fundamental problems, including little water, much sediment, inharmonious relations between water and sediment, fragile eco – environment of the river, etc. to provide guidance to the control, development and management of the Yellow River at the new period.

**Key words:** production system, the river management means, three Yellow River, decision – making support system, maintaining the healthy life of the Yellow River

## 1 Severe survival crisis encountered by the Yellow River and its fundamental problems

### 1.1 Strict survival crisis faced by the Yellow River life

After having experienced a large scale management and development in the Yellow River, tremendous achievements of flood control (inc. ice jam control), sedimentation reduction, irrigation, water supply, power generation, etc. have been obtained, at the time of promoting the socio – economic development of the local areas, the Yellow River is also facing a serious crisis in survival in the following four aspects:

(1) Acute conflict between demand and supply of water resources, occupancy of a great deal of ecological water and frequent occurrence of zero flow in the river course. The annual average runoff consumed at present in the Yellow River basin and its adjacent areas amounts to over 30 billion  $m^3$ , 2.5 times increase from that of 1950s. The utilization rate is close to 70% that exceeds the international recognized warning limit of 40%. Due to a great lot economic use, the water for sediment transport and eco – environment has been occupied greatly, resulting in the flow cutoff frequently occurred in the lower Yellow River for a time. Although the flow cutoff has been alleviated, as the result of integral water regulation being enforced on the main stream of the river since 1999, the situation of water shortage is becoming more and more rigorous and the problem of functional flow cutoff is not resolved as yet for the basin locates in the region lack of water resources, and with socio – economic development.

(2) Aggravation of riverbed shrinkage, sharp drop of water – passing capacity, and huge menace of flooding water. In recent 20 years, the main channel of the lower river course has shrunk due to sedimentation. 0.223 billion t of sediment was settled down annually in average during 1985 ~ 1999, of which 72% rested on the main channel, causing a sharp reduction of its capacity in passing water from 6,000 ~ 6,500  $m^3/s$  (bankful discharge) at the beginning of 1980s to about 1,800  $m^3/s$  at some sections in 2001. As a result, “the 2nd suspended river” developed rapidly. At the same time, the water – passing capacity of the main channels of Ningxia – Inner Mongolia river section in the upper reaches, and that of the channel of Weihe River (the largest tributary of the Yellow River), have also evidently lessened when water level risen noticeably with medium and small floods and bankful discharge reduced significantly, seriously threatening the safety of the lower Yellow River against flooding.

(3) Soil and water loss has not been effectively kept within limits yet. The Loess Plateau covers a large area of soil and water losses, with the biggest erosion modulus in the world. It contributes about 1.6 billion tons of sediment to the Yellow River annually. The area with annual erosion modulus of greater than  $1,000 \text{ t/km}^2$  extends  $454,000 \text{ km}^2$ , accounting for 71% of the entire plateau. With more than 50 year's consistent and persistent land and water conservation work, the soil and water losses at the Plateau have been reduced to some extent and the annual average reduction of 0.3 billion tons of sediment into the Yellow River since 1970. Nevertheless, the standard of the initially treated regions is at the low side, the works are not completely facilitated. Particularly, the pace of treating the area of  $78,600 \text{ km}^2$  where much coarse sediment originates has far lagged behind and its erosion modulus is much higher than the national standard of  $1,000 \text{ t/(km}^2 \cdot \text{a)}$  for slight erosion. With the rapid economic development and continuous increase of population at the Plateau, the claim from nature by human beings would constantly enhance, additional soil and water losses source be generated and much more pressure be put on environment.

(4) Grave water pollution and deteriorating of eco - environment of the river course and estuary. In accordance with "2004' Water Resources Quality Communiqué for the Yellow River Basin", among 32 monitoring sections on the main stem, water quality of 65.6% area is lower than Class III for surface water and the water source for drinking in near 70% cities along the main river could not reach the standard. Water quality at 76.5% of the cross sections, among the 51 observed at major tributaries, is worse than the standard of Class III. Deterioration of water quality not only directly influences people's health, but also greatly pricks up intensity of water shortage, exerts a most adverse impact on the ecological system of the river as well. Due to the quick dropping of water running into the sea in recent 10 years, the river delta has shown a worsening trend in ecology as: ①yearly reduction in the area and quality of wet land where inhabits the animals and plants whose population has distinctively become less; ②falling of the nutriment entering into the sea from the estuary, increase of salinity at surface, making offing aquatic animals near shore suffer grave impact; ③large scale economic development narrowed the area of natural reserve and surviving space of wild animals and polluted environment, interrupting natural evolvement and inhabiting environment for biological species.

## 1.2 Radical cause

The attentive analysis on the crisis mentioned above discloses that the real cause of these problems lies in little water, much sediment, inharmonious relations of the both, as well as fragile hydro - ecology environment, those are the critical issues remained to be resolved for a long term in the process of "maintaining the healthy life of the Yellow River", and shall run through the whole process of the development and management of the Yellow River in the future.

(1) Little water. There has been little water running in the Yellow River since ancient times. According to the statistics, of the annual mean runoff  $48.1 \text{ billion m}^3$  observed at Huayuankou in 1920 ~ 1949, only  $4.8 \text{ billion m}^3$  of surface water was used. The total water consumed for the socio - economic development of the river basin and its adjacent regions increased by 3 times and surface water increased by 2.8 times. The water consumed by industrial, agricultural and municipal sectors accounts for  $41 \text{ billion m}^3$  or so at present, including underground water of  $11 \text{ billion m}^3$ . It is expected that the water demand by these sectors would increase to  $53 \text{ billion m}^3$  and  $62 \text{ billion m}^3$  in 2020 and 2050 respectively with further socio - economic development, which requires the Yellow River supply water of  $42 \text{ billion m}^3$  and  $51 \text{ billion m}^3$  exclusive of ground water. Without supplement from outside water source, the contradiction between demand and supply of water resources would become more and more acute and the actual inflow would be much less.

(2) Much sediment. The Yellow River is well known, among the rivers in the world, for the greatest amount of sediment transport and the mostly heavy sediment concentration. The cause of much sediment contributes to severe loss of soil and water at the Loess Plateau. The textual research on the quantity and particle gradation indicates that there not only contains much sediment in the river, but also it distributes in a concentrated way as about 62.8% of full size sand and 72.5% of

coarse sand ( $d \geq 0.05$  mm in diameter) come from 78,600 km<sup>2</sup> area in the middle reaches (data of 1950 ~ 1960). Despite of decrease of the sediment flowing into the river owing to the functions of hydraulic structures, soil and water conservation, together with little rainfall, especially, rainstorm, the amount of sediment to be reduced by these measures should have a limit (estimate to be around 0.8 billion t). Therefore, much sediment as a basic feature still exists in the Yellow River.

(3) Inharmonious relationship between water and sediment. This inherent characteristic depends on the geological and climatic conditions in the river basin. Due to different origins of water and sediment, that the inflow comes from the upper reaches, while the sediment comes from the middle, inharmonious phenomenon was mostly witnessed in the upper reaches and that long run relationship was kept by way of unceasing raise of riverbed, frequent breach of dikes, change and migrating of river course. However, dike breach or change of river course is not permitted objectively since the lower river goes across densely populated Huang – Huai – Hai Plain with relatively complete industrial and agricultural production system. In that case, the conflict has become more prominent all because of the continuous increase of water used along the lower river, giving rise to the reduced magnitude of river runoff in excess of the sediment reduced and showing its tendency of further development. It can predict therefrom that the flood with a great quantity of discharge occurring on the main stream would further decrease, without additional water supply from outside basins and new key projects to be built in the future, thus, the contradiction and inharmonious relationship would be more outstanding and the river situation would be deteriorated further.

(4) Fragile aquatic eco – environment. This contradiction directly leads to extreme frailness of eco – environment of the river. Despite of the purgative function of the sediment into the river by physic – chemical reaction, such as adsorption and neutralization, its positive impact is unable to counteract the negative to the ecological environment, gradual reduction of water discharge, relative increase of both siltation and polluting release because water plays a prominent role in environment.

## **2 Principal measures for maintaining the healthy life of the Yellow River**

In a word, the aforesaid 4 fundamental problems have nagged the healthy life of the river for a long term, in consequence, the production system shall be built with an address on finding out the solution. The basic thought for resolving these problems shall be “increase water, decrease sediment, regulate the both and maintain sound development of aquatic ecological environment”. The major measures of “increase water” covers “effective management of the Yellow River water resources utilization” and “water transfer from other basins”. For “sediment reduction”, measures refer to decrease and disposal of the sand in the river. For “water and sediment regulation”, measures include “establishment of water and sediment regulation system for the river”, “lower river treatment”, “mould harmonious relationship of water and sediment” and “slow down extension rate of siltation at estuary”. For the 4th, measures include “lower pollution and runoff rate for water resources protection” and “maintain sound cycle of river ecological system”. The above 9 measures are independent and rely on each other as well. After their gradual implementation and being fully put into force, the target of “4 not” and maintaining healthy life of the river for a long time can be realized in principle.

### **2.1 Effective management of water resources and water transfer from other basins**

To solve the problem of water resources shortage, the effective management shall be strengthened and water saving society shall be established, on the basis of which, water transfer across basins shall be gradually carried out to increase the water resources of the Yellow River.

#### **2.1.1 Effective management of water resources**

By adopting administrative, economic, engineering, technical and legal means, a comprehensive guarantee system for unified water resources management and regulation of the

Yellow River shall be set up as the following: intensify planned water use and quota management, constitute rational configuration scenario for water resources, establish 3 series of water allocation indexes for water abstraction, water consumption and provincial cross sections, perfect water drawing permission system, practice unified allocation of water by the State, water discharge and quantity control at cross sections, provinces or regions responsible for water distribution, centralized regulation of major hydraulic works on the main stream and tributaries. Gradually justify water demand and supply amount by building and implementing water price and water right mechanism. The water source and ecology protection at riverhead shall be reinforced to recover its self – restraint function. Further improvement and strengthening of legal means ensures the implementation of unified management and regulation of water resources.

### 2.1.2 Building up of water saving society

Irrigation is the major factor on water saving. The potential of water saving by the Yellow River irrigated area is quite big since only 23.95 million mu (1.597 million  $\text{hm}^2$ ) or 20% of the irrigated area in the total has satisfied the criteria. The water utilized coefficient would, if water saving project is put into operation, be higher than 0.5 from the present 0.4, that means the amount of water saved shall reach 3.47 billion  $\text{m}^3$ . For the increase of 0.6, another 100% of water would be acquired. Hence, great efforts shall be put on innovation of water saving facilities and on the agricultural development of water saving type. Well and channel irrigation, and substitution of drainage by irrigation shall be performed in the irrigated area where conditions are available. For fully making use of rainfall resources, cultivating system reform shall be carried out to elevate dry farming production level. At the same time, structural adjustment and technical innovation, addressing water saving, shall be strengthened, the projects of much water consumption and heavy pollution shall be strictly forbidden, high – tech industries of high efficiency in water use shall be encouraged, and water saving by municipal and industrial use shall be well done.

### 2.1.3 Water transfer from the outside

Trans – watershed water transfer is a critical measure for solving the water shortage of the Yellow River, and the schemes currently identified include: ① the west line of South – to – North Water Transfer Project that is a fundamental way for solving water deficiency of the Yellow River; ② supplement water to the Yellow River as the circumstances require by east and middle line projects being constructed to relieve the water shortage for ecological use in the lower river course and estuary in the near term; ③ other water transfer projects as drawing water from Xiaojiang to Weihe River for the purpose of solving water shortage of the Weihe River and adequate makeup of water for ecological use in the lower reaches.

It is planned in the west line project to transport water from Daduhe, Yalongjiang and Jinshajiang upstream of the Yangtze River to the riverhead of the Yellow River, with the amount of 17 billion  $\text{m}^3$  water shifted, of which, 8 billion ~ 9 billion  $\text{m}^3$  will be offered by the first and second phases that is relatively easy to be implemented and to be taken effect prior to 2020.

## 2.2 Cut down and dispose the sediment

Where the trouble lies is sediment. Through practice and research on taming of the Yellow River for a long period, the essential thought of reducing, disposing and utilizing of the sediment of the river shall still follow the comprehensive measures of “retaining, drainage, releasing, regulation and excavation”. Among those, the address on “retaining and releasing” shall be laid on the dangerous coarse sediment deposited on the main channel, consequently, “three defense lines” shall be structured soon: ① at the time of persistent soil and water conservation of the Plateau, following the principle of “first coarse and second fine”, perform overall treatment on soil and water losses to minimize the coarse sand entering into the river by a major mean of building check dams; ② make use of dead storage capacity of the key projects on the main stem in both upper and middle reaches to hold back the coarse and discharge the fine sediment flowing into the middle and lower

reaches; 3) mostly rely on the vast floodplain of Xiaobeiganliu for warping to further intercept a part of coarse sediment into the Xiaolangdi and the lower reaches. In addition, the floodplain below Xiaolangdi can be used for directing flooding water against sedimentation, resulting in the reduction of sediment into the lower course and estuary when the Xiaolangdi releases the small flood with heavy sediment concentration.

### **2.2.1 Soil and water conservation of the Loess Plateau**

The prevention of soil and water losses shall be in accord with the strategies of “combination of prevention and control, giving priority to protection and reinforcing treatment”. Not only investment increase, necessary measures of integrated treatment by manpower and ecological rehabilitation, but also prevention and supervision to avoid new losses during development and construction shall be executed. The area of 78,600 km<sup>2</sup> with much coarse sediment in the middle reaches shall be emphasized for treatment in a short term, in particular, the source area of coarse sediment (18,800 km<sup>2</sup>) that exerts a great impact on the lower riverbed shall be regarded as a breakthrough for prior consideration and concentrated arrangement so that the first defense line can be structured soon, taking sediment retarding works and check dams construction as the main on the major tributaries.

### **2.2.2 Trap sediment by key works**

The total capacity in retaining and reducing sediment, after the completion of key projects on the main stream and tributaries excluding longyangxie, Liujiaxia and Sanmenxia, can reach over 50 billion t, as the result, the sediment into the lower river course and alluvial rivers in the upper and middle reaches would be reduced noticeably within a certain period. The Xiaolangdi can provide sediment reduction by 10 billion t prior to 2020 (1.5 billion t of sand has been held back by it). Guxian is to be constructed in 2020 for retarding sediment of 16 billion t after 40 years' operation, with annual mean sediment reduction of 0.4 billion t into the river course below Longmen. Daliushu and Qikou on the main stem and Dongzhuang on Weihe tributary will be set up, following Guxian, for operation of 40 ~ 60 years to intercept 24 billion t of sediment. “Retard the coarse and release the fine” by the reservoirs and joint regulation of both water and sediment can further reduce the sediment into the lower reaches.

### **2.2.3 Xiaobeigangliu warping**

The warping will be in three phases; without warping test, without warping and with warping. In the early 2 ~ 3 years, basic data will be obtained by without warping testing, based on which, a preliminary without warping engineering system will be built up in 2010 and a complete system will be formed prior to 2025. It is planned to have a total warping area of 303 km<sup>2</sup> to block 1.2 billion t of sediment. Yumenkou Project in Beigangliu of the river will be constructed for the dominant purpose of warping as a long term plan, together with Guxian Reservoir upstream to expand warping area and raise efficiency. About 10 billion tons of sediment can be settled on the floodplain of both banks of Xiaobeiganliu by warping, of which 40% is coarse sediment.

## **2.3 Set up water and sediment regulation system for creation of harmonious relationship**

As for solving the problem of inharmonious water and sediment relations of the Yellow River, except for the aforesaid measures of water increase and sediment reduction, a prefect water and sediment regulation system shall be set up. By a joint regulation of key projects on the main stem and tributaries, to shape harmonious relations, recover and maintain the flood discharge and sediment transport capacity of the main channel at alluvial river can be exercised.

### **2.3.1 Major means for recovering and maintaining the river channel for medium flood at alluvial river section on the main stem and tributary**

Long period practice and research results indicate that bed – forming force of floods shall be fully made use of in order to regain and maintain the river channel for medium flood, with somewhat

flow passing capacity, at alluvial river section on the main stem and tributary. There are three ways for doing so, according to occurrence possibility with different flooding magnitudes. As for major and extraordinary floods, in the light of scientific and reasonable flood management scheme, by way of joint operation of the reservoirs on the main stem and tributaries and timely operation of detention basins, on the premise of ensuring no dike breach, the functions of alluvial river course in much sediment discharge by major flood and floodplain sedimentation and channel flushing shall be fully brought about, for the purpose of enlarging cross section of the main channel and lowering transverse gradient of floodplain. For medium floods, on the principle of rationally undertaking moderate risk, a coordinated water and sediment relationship will be created by joint regulation, flooding water is made to shape river channel and to carry sediment into the sea for restoration of river channel's carrying capacity. If there is no flooding water in the river and the condition is ready, artificial flood shall be created by way of joint regulation of reservoirs to obtain the objectives of flushing main channel, stop the main channel from shrinking and flush much more sediment to the sea. In addition to flood control, utilization and creation, auxiliary measures such as artificial warping and river channel dredging can be employed for restoring and maintaining river channel of medium flood.

Three times of water and sediment regulation testing results on the Yellow River during 2002 ~ 2004 show that the regulation is a crucial measure in restoring and maintaining the river channel. 4 major reservoirs of Longyangxia, Liujiaxia, Sanmenxia and Xiaolangdi have been put into operation on the Yellow River at present, equipped with a total storage capacity of 51.7 billion  $\text{m}^3$  and effective storage of 28.6 billion  $\text{m}^3$ . The four have played a huge role in flood control, ice jam control, sediment reduction, water and sediment regulation, and water allocation, providing a strong support to sustainable development of socio-economy at local regions, but with a limit in water and sediment control. Nevertheless, without effective measures taken, the situation of river channel narrowing downstream of Weihe River still remains. Therefore, for realizing of the targets thereabove, building of a complete water and sediment control and regulation system, water transfer from the foreign basins, joint water and sediment regulation by reservoirs and moulding of harmonious relationship shall be conducted.

In accordance with water and sediment characteristics of different river sections, a new river management concept, the requirements of coordinating the relationship and river control, in view of the whole basin, a complete water and sediment regulation system will be generated, consisting of 7 critical reservoirs of Longyangxia, Liujiaxia, Heishanxia, Qikou, Guxian, Sanmenxia, and Xiaolangdi on the main stem and Luhun, Guxian, Hekoucun and Dongzhuang reservoirs on tributaries, to heighten the capacity in management and control of flood and sediment at different river sections, turning disadvantageous water and sediment process into the advantageous, adaptable to the sediment transport feature, raising sediment delivery efficiency, reducing sedimentation, saving water for sediment flushing.

### **2.3.2 Water and sediment regulation in a short term**

Prior to the completion of South-to-North Water Transfer West-line Project, Guxian and Heishan projects, the existing reservoirs of Wanjiashai, Sanmenxia, Xiaolangdi, Luhun and Guxian shall be jointly operated to amplify the main river channel capacity in passing flow to 4,000 ~ 5,000  $\text{m}^3/\text{s}$ , and to keep down the Ningxia- Inner Mongolia main channel shrinkage trend and lower the elevation of Tongguan riverbed.

### **2.3.3 Water and sediment regulation in a middle term**

In 2020 when Guxian and Daliushu reservoirs on the main stem, Hekouchun and Dongzhuang reservoirs on tributaries are put into operation, the west line project will provide 8 billion ~ 9 billion  $\text{m}^3$  of water to the Yellow River. Daliushu Reservoir will regulate the water in the Yellow River and the water allocated by the west line project, and collect a great amount of water for discharging in flood season for creation of water and sediment relationship, good for the sediment delivery of the Ning-Meng river section in order to restore its main channel capacity to over 3,000  $\text{m}^3/\text{s}$ . By way of joint operation of Guxian, Sanmenxia, Xiaolangdi and Hekouchun, the water and sediment



discharged from the upstream reservoirs and inflow and sediment from the middle reaches will be adjusted to generate the relationship favorable for river course sediment transport, turning disadvantageous condition into the advantageous, mitigating the sedimentation on Xiaobeiganliu and its lower river, lowering Tongguan elevation, recovering the water passing capacity of the main channel as well. Meanwhile, Dongzhuang reservoir on the tributary—Weihe River will hold back sediment and regulate water and sediment, with water withdrawing from outside, to alleviate the siltation on the downstream of Weihe River for the recovery of its flow passing capacity of  $3,000 \text{ m}^3/\text{s}$ .

### 2.3.4 Water and sediment regulation in a long term

Upon the completion of Qikou Project, a perfect water and sediment regulation system for the Yellow River will be formed to carry out a joint operation of 7 major projects on the main stem and of other reservoirs on the tributaries, to regulate flood water, runoff, sediment and the water offered by the west line project, coordinate water and sediment relations, create favorable water and sediment conditions at the alluvial river sections, decrease sedimentation, generate and maintain the river channel for medium flooding water passing. With the water transfer projects outside being put into effect gradually, the water transported to the Yellow River will measure 14 billion ~ 17 billion  $\text{m}^3$  in the future. To further increase water quantity for sediment delivery through rational allocation, fully bring the system into play and harmonize water and sediment relations would achieve a scouring and siltation balance of the main river channel in some way, maintain some water carrying capacity of the river channel for medium floods and maintain the healthy life of the Yellow River.

## 2.4 Lower river course control

Due to long period of sedimentation, the lower Yellow River is well known as “suspended river above ground”. Dike breaching and river course shifting had been happened frequently and flooding disasters had been extremely serious before 1946. As the flood way, the spacious floodplain of the lower Yellow River inhabits 1.81 million residents, it is of great importance in ensuring the safety against floods and realization of harmonious existence of the people and water there.

### 2.4.1 Strategy

In compliance with the knowledge of water and sediment conditions of the lower Yellow River in the future, river management practice and abundant research results and requirements of scientific development, on the premise of forming a flood control engineering system of “upstream retaining and downstream discharging of sediment, separated detention of flood water along both banks”, scientific and rational strategies for a new period have been brought up: “stabilize main channel, regulate water and sediment, widen river and consolidate dikes, complement by policy.” The meaning can be read as follows. By further improvement and construction of river training works, shifting, changeable characteristics of the lower river will be altered, and middle flow path be stabilized; besides, water and sediment regulation can make the river channel for medium flood keep some capacity in flooding water transport and sediment discharge for the restriction of overbanking. For the river section upstream of Toachengpu, widening river and consolidating dikes scheme will be adopted. In line with the existing works layout, dikes are to be reinforced further for standardization. The river channel for medium flood is shaped for releasing both flood water and sediment when floods of medium and small sizes take place, whereas, spacious floodplain shall be depended on for major floods for flood detention and sediment settling, to strengthen flood passing capacity of the main channel. The floodplain safety construction can let the people there enjoy a good and prosperous life when a medium flood occurs, and the lives and properties of the people can be pledged safety when a major flood takes place. The supplementary policy for the floodplain will help the farmer to resume their production.

### 2.4.2 Controlling measures for the lower river course

(1) Construct standardized dikes. The dikes are regarded as an important barrier to achieve a

goal of widening river and reinforcing dikes, as well as guaranteeing “no breach” at the time of flood occurrence with discharge of 22,000 m<sup>3</sup>/s at Huayuankou. The dikes after gradual improvement and perfection will become “flood control guarantee line, traffic line for rescue and ecological landscape line”.

(2) River training works construction. Before the source area of sediment being under effective control, a good opportunity of initial operation of Xiaolangdi shall be fully utilized. The training works are reasonably arranged in the meandering section—Tiexie – Gaocun of 299 km long to lessen a scope of main current shifting and swinging until 2010 when the shifting river regime is under control in principle, the safety of the lower reaches ensured and sediment transport access of high efficiency created day by day.

(3) Strengthen comprehensive management on floodplain and set up policy supplement mechanism. Different from other rivers in China, the Yellow River floodplain is not only for flood running, detention and sediment settling, but also the place inhabiting more than 1.8 million people. In line with local conditions, three sorts of measures for floodplain safety construction are worked out, i. e. migration, temporary evacuation, resettlement locally at the concentrated towns. In accordance with the topography there, it is preliminarily planned to migrate about 467,000 people and to evacuate temporarily about 390,000 people when flooding, the remaining people will be moved to the platform built locally with the criteria of coping with 12,370 m<sup>3</sup>/s flood discharge at Huayuankou (a 20 – year occurrence). Being a special detention zone, the floodplain of the lower reaches shall have a certain amount of compensation from the central government after flooding has happened. In terms of the prominent problem of “suspended river section” from Dongbatou to Taochengpu, in cooperation with water and sediment regulation, some feasible measures as dredging up the main channel, warping, blocking up series of gullies, filling dikes, drawing flooding water for floodplain forming, etc. shall be taken, to speed up river management pace, stop river shrinkage, and mitigate the adverse impact produced by the 2nd suspended river on the flood control.

## 2.5 Control estuary and alleviate its extension rate due to siltation

As one of the rivers with the heavysset sediment in the world, the Yellow River delivers around 1 billion tons of sediment to the estuary every year (Lijin station, 1950 ~ 1987). Unfortunately, the dynamic force of the flow is so weak that the sediment is unable to be transported into the sea far enough, but settles down the estuary and shallow sea region, which cause the rise of erosive base level and results in a unfavorable condition for flood prevention. In order to minimize the adverse impact of siltation extension, estuary treatment shall be strengthened to slow down the sediment deposition rate.

### 2.5.1 Rational arrangement of flow route into sea

In the interest of fully using of receiving sediment capacity of Qingshuigou flow path, slowing down estuary extension pace, ensuring the safety of the lower river against flood and ice jam, being favorable for the development of Yellow River delta and Shengli Oil Field, the sedimentation on the estuary shall spread in wider fan – shape. Based on the change prediction of scouring and siltation on Qingshuigou, its flow shall be arranged to run to the sea via. Beicha. The present analysis indicates that the life of Qingshuigou flow path is quite limited. At one time, a reserve flow route shall be left in case of special situation taking place. It was planned in the past to use Diaokouhe as the prior standby and Maxinlu as the second path. “Yellow River Estuary Management Method” published shall be followed to strengthen the care of the standby flow path for future use.

### 2.5.2 Intensify Weilu River treatment

According to the forecasting on inflow and sediment to the estuary and flow path change tendency, Qingshuigou will work over 30 years. For the sake of increasing the current flood discharge and sediment transport capacity of Qingshuigou, alleviating retrogressive siltation impact

on the lower river and ensure the estuary safety against flood, the dikes and river training works at Weilu River shall be strengthened to relatively stabilize flow path into the sea, with a guarantee of no breach of dikes there when a flood of  $10,000 \text{ m}^3/\text{s}$  is taking place. Furthermore, river excavation and dredging at the estuary shall be conducted to relieve sedimentation on the main channel and make retrogressive scouring occur under certain water and sediment conditions, which is favorable for clear and stable flow path and plays a function of sediment reduction at local river section upstream as well. The sediment excavated can be used for dike construction so as to achieve the target of organic combination of “excavation” and “discharge”.

### **2.5.3 Slow down silting extension of estuary**

In order to slow down silting extension of the estuary, except for the measures to minimizing of the sediment into the estuary mentioned above including comprehensive treatment of soil and water losses at the Loess Plateau, the key works on the main stem for sediment retarding, warping of Xiaobeiganliu floodplain, some other measures shall be employed to enlarge disposing area and piling space and try to reduce sedimentation on Weilu River course and shallow sea. Those measures include sand ridge treatment works, increasing sediment transport quantity into the sea by fully using of marine power, directing flooding water for warping at low – land of both banks for land melioration, land forming by sediment, in combination with oil field exploitation, etc.

## **2.6 Protect water resources and maintain a good cycle of river ecological system**

### **2.6.1 Water resources protection**

The current severe water pollution has affected drinking water and river ecological safety. It preliminarily estimates that the direct economic loss caused by the water pollution amounts to 11.5 billion ~ 15.6 billion RMB yuan. The crux to realize “not exceeding pollution standard” is to lower pollution and runoff ratio by decreasing pollutant discharge and increasing the water quantity of the Yellow River. On the basis of intensifying government surveillance and management, enough attention shall be given to playing full functions of local government, environment protection and water conservancy departments, overall planning of water conservancy and environment protection, policies of unified pollution treatment and working in cooperation with a due division shall be pursued, and a joint pollution control mechanism shall be established. Regarding water resources protection as a fundamental task, on the basis of ensuring polluting source of the basin up to the standard, the total pollutant discharge load control shall be executed by legal, administrative, economic, technical, and consensus means necessary and engineering measures. Through the South – to – North Water Transfer Project and unified water allocation, the water quantity of the Yellow River will be increased and regulated, and river water resources and aquatic environment bearing capacity will be enhanced and optimized.

### **2.6.2 Keep a good cycle of river ecological system**

The Yellow River ecological system, being a complex one, consists of a series of sub – systems; terrestrial and aquatic ecological systems, associated wetland and marsh systems. The system is composed of three portions of riverhead, main stem and estuary, representing varieties of natural zones and corresponding ecological characteristics of the Yellow River. The riverhead area, sparsely populated with a vast area, shall be put protection first as a whole, rely mainly on natural rehabilitation and economic activity regulating of human beings while making manpower and ecological construction subsidiary. To adopt managerial, ecological and engineering measures recover grassland at paramos so as to gradually produce a good cycle there. For the main stem, joint efforts of protection and development shall be taken, on the premise of satisfying normal requirements of human beings, the water demand for ecological purpose shall be guaranteed by engineering, managerial and ecological measures to renew aquatic ecological system and repair wetland ecological system. The major measures adopted for the estuary are: ① reinforce effective management and optimized regulation of water resources for ensuring of no flow cutoff at the estuary

and basic water quantity necessary for maintaining ecological cycle of the delta; ② correctly deal with the relations between the estuary control and delta socio – economy development, divide ecological function zones in the estuary control scheme for optimizing the general layout; ③ consolidate rule of law building to supply legal support.

### 3 “Three Yellow River’s” technical means

“Maintaining the healthy life of the Yellow River”, as the ultimate target of control, development and management of the Yellow River, shall be successfully achieved by building up contemporary water conservancy concept and by way of up – to – date technical means that is the decision – making support system of “Three Yellow River”, i. e. the Natural Yellow River, Digital Yellow River and Lab’ing Yellow River. Only by the “three Yellow River” technical means, every ways of treatment can be ensured to be advance in technology, rational in economy, safe and reliable.

The Natural Yellow River refers to the river in nature that is the object of our research, control, development and management. The Digital Yellow River, as virtual contrast of the Natural Yellow River, with the help of modern and traditional means, basic data can be collected and the digital integrated platform and virtual environment with such elements as nature, economy, society, etc. of the entire basin and related regions are structured, based on which, varieties of schemes, with powerful system software and mathematical model, can be simulated, analyzed and studied, in addition, decision – making support can be provided visually to amplify the decisions of scientific and predicting features. The Lab’ing Yellow River is a physical contrast of the Natural Yellow River. By physical imitation technique all kinds of technical elements of the Natural Yellow River are reduced in a scale. Relative independent and mutual correlation physical model system can be made up according to the classification of research objects. The natural phenomena reflected by the natural Yellow River will, using this means, be inverted, simulated and tested, also for synthetic element, a single factor “peeling” can be performed so as to reveal inherent law implied in the prototype Yellow River.

The “Three Yellow River” mutually correlates and acts on each other, to structure together a “field” for scientific decision – making. In this “field”, the natural Yellow River is the basis of digital and lab’ing Yellow River, and the research object of them as well. With the help of a series testing means, the construction of the natural Yellow River mainly aims at acquiring raw data from it, and also through the analysis on some major issues existed, all sorts of requirements of control, development and management for the Yellow River will be raised. The main purpose of the digital Yellow River is to carry out early simulation on the scenario for the control, development and management of the Yellow River by making full use of the superiority of prompt reaction and low cost, then several alternatives, or their tendency and direction can be put forward. The lab’ing Yellow River is constructed mainly for the sake of conducting the analog testing on the potential scenario proposed by the digital Yellow River, from which, feasible schemes for the natural Yellow River can be selected or perfected using the function of Lab’ing Yellow River, similar to actual flow field in nature. It deems thereof that the Lab’ing Yellow River is an “intermediate testing” link between the mathematical simulation and analyses by the digital Yellow River and making proposal of schemes for the natural Yellow River. At the same time, the physical model testing can provide the parameters for the establishment of the digital Yellow River, that makes the mathematical simulation system is meaningful in physics to well accord with the Yellow River reality. Eventually, the feasible schemes proposed after Lab’ing Yellow River testing will be laid out or implemented, gradually regulated and stabilized through the practice of the natural Yellow River to make the schemes with advantageous of advanced technology, rational economy, safety and effectiveness come true.

### 4 Assurance measures

The control, development and management of the Yellow River, featuring of special

importance, complex and difficulty, are a huge systematic project across regions and departments. In order to coordinate all relations among regions and departments concerned, guarantee smooth performance of control, development and management of the Yellow River, promote sustainable utilization of water resources, basin eco – environment construction and sustainable development of socio – economy in the associated areas, achieve the ultimate target, together with carrying out 9 river control means and building up the decision – making support system for the “three Yellow River”, the construction of assurance system shall be intensified including the research and establishment of watershed management, engineering management, investment security mechanism and building rule of law system, etc.

## 5 Implementation procedures and anticipated results

To realize the ultimate target of “maintaining the healthy life of the Yellow River” is a long and arduous historic task. Through gradual accomplishment of water increase, sediment reduction, water and sediment regulation, recovering of river eco – environment so as to reach the anticipated results of containing the “morbid state” development of the Yellow River, reinstating the basic function of the river course and maintaining healthy life regime of the Yellow River”.

### 5.1 Short term

This period refers to the time prior to the effect of the 1st phase of the west line project. By intensifying the Loess Plateau control, annual average sediment into the Yellow River reduced totals in 0.4 billion ~ 0.5 billion t, however, the water demand owing to quick economic development is unavoidable, the inflow to the Yellow River will decrease further and the situation of little water, much sediment and inharmonious relations of the both continuously develop towards aggravation. Major objectives are: ① basically finish standardized dikes for ensuring of no dike breach if flood peak discharge at Huayuankou measures 22,000 m<sup>3</sup>/s, control meandering river regime in principle and stabilize the main river channel, do well in water and sediment regulation by the existing reservoirs, regarding Xiaolangdi as a center so that the flow passing capacity of the main channel can be restored to 4,000 ~ 5,000 m<sup>3</sup>/s, relatively stabilize flow path into the sea, the flood control structures at critical river sections in upper and middle river stems shall attain to design criteria; ② perfect integrated management and regulation system for water resources, fortify water resources demand management, achieve initial success in building up of water saving society and ensure no flow cutoff of the Yellow River; ③ set up a joint pollution control mechanism, satisfy total load requirement on the pollutant entering into the Yellow River, and restrain worsening trend of wetland ecological system; ④ basically control new soil and water losses due to human beings activity, reinforce the disposing of coarse sediment source area to effectively lessen the coarse mostly dangerous to the lower river course and stop eco – environment worsening tendency of the Loess Plateau.

### 5.2 Middle term

This period refers to the time between after the effect of the 1st phase of the west line project and before the 2nd stage project completion. The soil and water conservation of the Plateau will decrease 0.6 billion ~ 0.7 billion t of sediment into the Yellow River yearly in total. Supplement water to the Yellow River in an appropriate time by east and middle line projects and operation of the 1st stage of west line project can add over 4 billion t of water, as the result, the water and sediment relations can be somewhat improved. Major target are: ① further decrease the sediment into the Yellow River, further improve water and sediment system construction, complete Guxian and Hekouchun reservoirs, commence the building of Daliushu, Qikou and Dongzhuang reservoirs, and accomplish integrated treatment works on floodplain; ② effectively control and manage flooding water by the key reservoirs on the main stem and tributaries for recovering of the basic function of

the river course and for creating stable river channel for medium flood; ③ all the Yellow River irrigated areas reach the water saving requirements, municipal and industrial water saving is up to the advanced national level, and water saving society see major results; ④ strengthen joint pollution control mechanism, the sewage water discharging into the Yellow River under control and the water quality of the entire river reaches the goal for water functioning zone; ⑤ provide the basic amount of water for keeping the ecological system balance of the estuary wetland and gradually resume its good cycle for the realization of people and water in basic harmony.

### 5.3 Long term

That means after completion of the 2nd stage works of the west line project. The soil and water losses area suitable for treatment in the Plateau is to be dealt with in principle, yearly average sediment reduction into the Yellow River will amount to 0.8 billion t, additional water of around 5 billion m<sup>3</sup> will transfer to the Yellow River by the 2nd stage works of the west line project so that water and sediment relations will be further improved. Major goals are: ① build a perfect water and sediment regulation system, effectively control the flood and sediment, form “relative underground river” so as to actualize long period stability of the Yellow River; ② create water saving society, basically solve the demand and supply conflict of the water resources, and the surface water quality of the basin comes back to goon state; ③ achieve a good cycle of eco – environment of the basin; ④ make “no dike breach, no flow cutoff of the river course, no polluting exceeding standard, no raise of riverbed” come true, maintain the healthy life of the Yellow River, and realize the harmonious existence of people and the Yellow River.

# Study on River Health Evaluation Method

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**Abstract:** Since river system is of dissipative structure, the evaluation of river health can be studied from point of the systematic view. With application of system and information theories, this paper presents a method to evaluate the river health based on system order degree entropy. The River Health Index is deduced with consideration of multiple subsystems or health targets of the river. An example of the Yellow River is given, in which, the river health factors and its threshold parameters are put forward, and the current health situation is evaluated.

**Key words:** river, health, entropy, evaluation

## 1 Introduction

River is closely related to human civilization course. In a certain meaning, human growth and development relies on river, and this can be proved by countless ancient and modern civilization. Human civilization progress can receive benefit from river on one hand and can bring about impact on river on the other hand. In the civilization course, human needs more and more water resources to support his development, the need even surpasses the bearing capacity of river at a certain time, and the health of river itself will be impacted consequently. the Yellow River can be taken as an example. Since water consumption by human surpasses the bearing capacity of basin water resources, a series of social, economic and ecologic problems have appeared. For instances, main channel shrinks greatly, secondary suspended river is sped up, contradiction between water resources supply and demand is getting prominent, frequent zero – flows appear in river channel, water quality is worsened in most river sections, and river ecosystem deteriorates.

This study focuses on how to evaluate river health for the purpose of realizing the harmony between human and nature. It is known that river system is a dissipative structure, and the evaluation of river health can be studied from point of the systematic view. With application of system and information theories, this paper presents a method to evaluate the river health based on system order degree entropy. The River Health Index is deduced with consideration of multiple subsystems or health targets of the river. An example of the Yellow River is given, in which the river health factors and its threshold parameters are put forward, and the current health situation are evaluated.

## 2 Method to evaluate river health based on system order degree entropy

With application of system theory, information theory and water resources critical controlling theory, a method to evaluate the river health based on system order degree entropy is presented and River Health Index is deduced in this paper to evaluate the river health.

### 2.1 Entropy and dissipative structure

About 140 years ago, R. Clausius, a German physical scientist, defined the ratio of heat and temperature for material absorption in reversible process as Entropie which is referred as  $S$ , and entropy is further interpreted as a quantized index for information description later on.

According to dissipative structure theory, a non – linear open system ( whether physical,

chemical, ecologic, even social, economic system) far away from equilibrium state has a non – linear power process and positive and negative feedback mechanism through continuous exchanges of material, energy and information with the outside; when a parameter change in the system reaches a certain threshold, the system may have a sudden change, e. g. , non – equilibrium phase change after fluctuation and negative entropy increase, being turned into a orderly new dissipative structure in time, space or function from the original disorderly state.

## 2.2 Method to evaluate dissipative structure evolution

For dissipative structures including river system, etc. , not all system phase changes can result in a new ordered state, some may result in a disordered state. Consequently, a concept, i. e. order degree, is recommended to judge the coordination function so as to control the system coordination degree for a promotion of a better system order. Since the system has  $k$  subsystems, each subsystem is referred as order parameter group  $e_j$ , i. e. ,  $j = 1, 2, \dots, K, K \geq 1$ . Supposing order parameter variable is  $e_j = (e_{j1}, e_{j2}, \dots, e_{jk})$  in evolution of subsystem  $e_j$ , the order degree of  $e_{ji}$  is defined as  $U_j(e_{ji})$ , and  $U_j(e_{ji}) \in [0, 1]$ .

$e_{ji}$  values shall be in the critical threshold limit, e. g. ,  $\beta_i \leq e_{ji} \leq \alpha_i$ . Supposing  $e_{j1}, e_{j2}, \dots, e_{jm} (1 \leq m \leq p)$  are bigger values in threshold limit, the order degree will be higher, and vice versa. Supposing  $e_{jm+1}, e_{jm+2}, \dots, e_{jp} (m \leq p \leq n)$  are bigger values in the critical threshold limit, the order degree will be lower, and vice versa. Supposing  $e_{jp+1}, e_{jp+2}, \dots, e_{jn}$  are closer to a certain value  $c$  in the critical threshold, the order degree will be higher. Therefore, order degree  $U_j(e_{ji})$  for parameter variable  $e_{ji}$  of order  $e_i$  will be as follows:

$$U_j(e_{ji}) = \begin{cases} \frac{e_{ji} - \beta_{ji}}{\alpha_{ji} - \beta_{ji}} & i \in [1, m] \\ \frac{\alpha_{ji} - e_{ji}}{\alpha_{ji} - \beta_{ji}} & i \in [m + 1, p] \\ 1 - \frac{e_{ji} - c}{\alpha_{ji} - \beta_{ji}} & i \in [p + 1, n] \end{cases} \quad (1)$$

in which:  $U_j(e_{ji})$  is order degree for order parameter variable  $e_{ji}$ ,  $\beta_i$  and  $\alpha_i$  are minimum and maximum critical thresholds for  $e_{ji}$  respectively.

The above Equation (1) shows: in case of order degree value for order parameter variable  $e_{ji}$  is  $U_j(e_{ji}) \in [0, 1]$ , the order parameter variable will be in the critical threshold limit, and the bigger the value is, the greater contribution will be presented to order degree  $e_i$  by  $e_{ji}$ . Otherwise, in case of  $U_j(e_{ji}) \notin [0, 1]$ , it means that  $e_{ji}$  is not in the reasonable threshold limit and shall be adjusted. In general, the total contribution presented by order parameter variable  $e_{ji}$  to order degree  $e_i$  can be realized through integration of  $U_j(e_{ji})$  as follows:

$$U_j(e_j) = \sum_{i=1}^n \lambda_i U_j(e_{ji}), \quad \lambda_i \geq 0, \quad \sum_{i=1}^n \lambda_i = 1 \quad (2)$$

$U_j(e_j)$  is the order degree for order parameter group  $e_j$ ,  $U_j(e_j) \in [0, 1]$ . The bigger  $U_j(e_j)$  is, the greater contribution will be presented by  $e_j$  to the whole system order degree and the higher order degree the system will be in, and vice versa.  $\lambda_i$  is the weight coefficient for order parameter variable  $e_{ji}$ , the actual operation shall be taken into consideration and the development aim of the system in a certain period shall be reflected when  $\lambda_i$  is determined.

Since a system has multiple order parameter groups  $e_j (j = 1, 2, \dots, K)$ , system order degree entropy  $S_Y$  is presented to evaluate the state of system evolution according to the definition of information entropy and with the application of order degree  $U_j(e_j)$  of  $e_j$ . The smaller the river system order degree entropy is, the more healthy the river system will be.



$$S_Y = - \sum_{j=1}^K \frac{1 - U_j(e_j)}{K} \ln \frac{1 - U_j(e_j)}{K} \quad (3)$$

### 2.3 River health index

River health index is presented based on the above river system order degree  $S_Y$ . First, a river will be in the middle health degree if the order degree threshold of each order parameter variable in the river system is defined as mid - value. In such cases:

$$U_j(e_{\bar{j}}) = \frac{1}{2} \quad (j = 1, 2, \dots, K; i = 1, 2, \dots, n) \quad (4)$$

$$U_j(e_j) = \frac{1}{2} \quad (j = 1, 2, \dots, K) \quad (5)$$

System order degree entropy  $S_Y$  for river in middle health degree can be obtained upon the substitution of Equations (4) and (5) in Equation (3), and it can be defined as  $S_{YM}$ :

$$S_{YM} = \frac{1}{2} \ln 2K \quad (6)$$

The ratio of the order degree  $S_{YM}$  corresponding to river's middle health degree and the order degree entropy of river system is taken as the river health index  $I_H$ , i. e.:

$$I_H = \frac{S_{YM}}{S_Y} \quad (7)$$

River health index  $I_H$  can be obtained upon the substitution of Equations (5) and (6) in the above equation.

$$I_H = - \frac{\ln 2K}{2 \sum_{j=1}^K \frac{1 - U_j(e_j)}{K} \ln \frac{1 - U_j(e_j)}{K}} \quad (8)$$

It can be seen from the above definitions that the river will be in middle health state in the case of  $I_H = 1$ , the river will be in sub - health or non - health state in the case of  $I_H < 1$ , and the river will be in basic health or health state in case of  $I_H > 1$ , in accordance with which river health can be evaluated.

River health index can also be adopted to evaluate the evolution orientation of river health after treatment and controlling measures are taken. If the river health index after treatment and controlling is bigger than the index before treatment and controlling, it means that the measures are favorable for river health, the river system is on the way of health and the controlling measures are reasonable. If the river health index after treatment and controlling is smaller than the index before treatment and controlling, it means that the measures are unfavorable for river health, the river system is on the way of non - health and the controlling measures are unreasonable.

### 2.4 Key problems in river health evaluation

River health degree can be evaluated based on Equation (8), and the key problems to be evaluated include: selection of system order parameter, analysis and evaluation of characters, development aim and main existing problems of river system, presenting of subsystem (order parameter groups) to be evaluated, and selection of quantized index for each subsystem, i. e., determination of order parameter variable  $e_j = (e_{j1}, e_{j2}, \dots, e_{jK})$ ; determination of reasonable threshold for order parameter, which is to determine target value and variation range, i. e., determination of threshold limit  $\beta_i \leq e_{\bar{j}} \leq \alpha_i$  of each order parameter variable  $e_{\bar{j}}$ , threshold being determined according to river situation and development planning; calculation of river health index and analysis of impact from controlling measures on river health.

### 3 Study on evaluating the healthy life of the Yellow River

Based on the analysis of the Yellow River water – sediment characters, existing problems and treatment aim, in accordance with the scientific, independent, objective and operational principle, and with reference of the related study results<sup>[2]</sup>, five order parameter groups are presented, including river state, river aquatic ecosystem, river water environment, supporting for human from river, and flood acceptance by river, and with application of 16 order parameter variables, study results of thresholds for each order parameter are presented, shown as Table 1. Limited by the problem complication and possibility for index obtaining, the order parameter groups and variable threshold for each parameter group presented in this paper are only the preliminary ones from study, and more work are required to make the index selection more scientific and comprehensive.

With the year 2000 as a representative, the Yellow River health is evaluated. The year 2000 is an extraordinary low flow year for the Yellow River. The actual inflow at Lijin Section is only 4.8 billion  $\text{m}^3$  in the whole year, in which the water volume into sea is only 3.1 billion  $\text{m}^3$  in non – flood season and 1.7 billion  $\text{m}^3$  in flood season, the minimum discharge in non – flood season is 30  $\text{m}^3/\text{s}$ , the downstream over – channel discharge is about 2,200  $\text{m}^3/\text{s}$ . The actual inflow at Hekouzhen Section is 14 billion  $\text{m}^3$  in the whole year, in which the inflow is 9.4 billion  $\text{m}^3$  in non – flood season and 4.6 billion  $\text{m}^3$  in flood season, the minimum daily discharge is 31  $\text{m}^3/\text{s}$ . The over – channel discharge in Ningmeng Section is about 1,000  $\text{m}^3/\text{s}$ . The water quality is in Grade III ~ Grade IV in upper reach and basically in Grade IV in middle and lower reaches. The surface water consumed and used for national economy in the basin is 29 billion  $\text{m}^3$  and the groundwater is 13 billion  $\text{m}^3$ . The flood control capacity is 5,900  $\text{m}^3/\text{s}$  in Ningmeng Section and 22,000  $\text{m}^3/\text{s}$  in lower reach.

Based on the actual values in 2000 for the 16 order parameter variables in the above five order parameter groups ( column c in Table 1 ) and the threshold for each of them ( column b in Table 1 ), the order degree  $U_j(e_{ji})$  for each order parameter variable  $e_{ji}$  is calculated with the application of Equation (1) and the result is shown in column d in Table 1; the order degree  $U_j(e_j)$  for each order parameter group can be obtained with the application of Equation (2) and with the idea of the same weight coefficient  $\lambda_i$  for each order parameter variable, and the result is shown in column e in Table 1; finally, the Yellow River health index  $I_H = 0.95$  in 2000 can be obtained with the application of Equation (8) with  $k=5$ , this shows that the current Yellow River is in non – health state. For the Yellow River which is highly developed and is artificially intervened, the reason for the non – health state is that the consumed and used water resources surpasses the bearing capacity of river water resources, and the water volume for keeping the river healthy life ( water for sediment transmission, water for ecosystem in non – flood season, etc. ) is used up by human, water – sediment relationship is not proper. Therefore, the important measure to recover the Yellow River health and to keep the healthy life of the Yellow River is to carry out basin – to – basin water diversion and mold a harmonious water – sediment relationship.

### 4 Conclusions

Theory of river healthy life is a new theory, and selection and evaluation of river health factors is a complicated scientific problem. In this paper, some studies have been carried out only from the view of system entropy, the studies show the current Yellow River health index is 0.95, indicating that Yellow River is in non – health state. However, further research and study on many problems are required. On one hand, study shall be conducted on health factor, dynamic character of threshold, and evolution character of health index, etc. , as well as on new method. On the other hand, research and study on the relationship between healthy life of river and basin development and treatment shall be carried out in order to provide technical support for basin development and treatment.

**Table 1 Index to evaluate the Yellow River healthy life**

Order parameter group	Order parameter variable (a)	Threshold (b)	In 2000 (c)	$U_j(e_{\mu_i})$ (d)	$U_j(e_j)$ (e)
1 River state	Water volume for sediment transmission in flood season in lower reach (at Lijin Section, $10^8 \text{ m}^3$ )	10 ~ 240	17	0.030	
	Over - channel discharge in lower reach( $\text{m}^3/\text{s}$ )	1,500 ~ 6,000	2,200	0.156	0.062,0
	Over - channel discharge in Ningmeng Section( $\text{m}^3/\text{s}$ )	1,000 ~ 5,000	1,000	0	
2 River water ecosystem	Minimum discharge in non - flood season in upper reach (at Hekouzheng Section, $\text{m}^3/\text{s}$ )	30 ~ 450	31	0.002	
	Water volume in non - flood season in upper reach (at Hekouzheng Section, $10^8 \text{ m}^3$ )	50 ~ 300	94	0.176	
	Minimum discharge in non - flood season in lower reach (at Lijin Section, $\text{m}^3/\text{s}$ )	30 ~ 300	30	0	0.057,3
	Water volume in non - flood season in lower reach (at Lijin Section, $10^8 \text{ m}^3$ )	30 ~ 150	31	0.008	
	Wetland area (with characterization of fresh water wetland in the core area of estuary natural protection zone, $10^4 \text{ hm}^2$ )	2 ~ 7	2.5	0.100	
3 Water environment	Upper reach	Grade II ~ III	Grade IV	0	
	Middle reach	Grade III ~ IV	Grade IV	0	0
	Lower reach	Grade III ~ IV	Grade IV	0	
4 Supporting from river for human	Surface water consumed and used for national economy( $10^8 \text{ m}^3$ )	250 ~ 450	290	0.200	0.400,0
	Groundwater consumed and used for national economy( $10^8 \text{ m}^3$ )	100 ~ 150	130	0.600	
5 Flood acceptance by river	Flood control capacity in Ningmeng Section( $\text{m}^3/\text{s}$ )	$\geq 5,900$	5,900	0.999	0.999
	Flood control capacity in lower reach ( $\text{m}^3/\text{s}$ )	$\geq 22,000$	22,000	0.999	

**Note:** Part of threshold represent the water - sediment relationship of the Yellow River and the worsening state.

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# Eutrophication Control and Environmental Restoration Using Reverse Osmosis Process in the Shichahai Lakes System

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**Abstract:** The Shichahai Project is an activity, supported by the Italian Ministry for Environment and Territory and the Beijing Environmental Protection Bureau under the Sino – Italian Cooperation Program, aimed to enhance the water quality of the Shichahai lakes system in Beijing’s urban area.

In a first phase, the pollution problems were investigated and the most appropriate measures to restore water quality in view of the 2008 Olympic Games were identified. Mainly, the lakes suffer from a diffuse eutrophic state that cannot be handled with the traditional approach of controlling the external nutrient loads. Consequently to control eutrophication, the solution to reduce the internal loads by continuous treatment of waters taken from the lakes with a “pump and treat” technique was selected. But, even in strong eutrophication status, the nutrients concentrations in surface waters are significantly lower than in wastewaters. Therefore two parallel goals are to be pursued: ① selecting a purification technique able to treat low concentration waters with high removal efficiency; ② identifying the optimal caption points so as to withdraw waters with the maximum available nutrients concentrations.

These objectives will be pursued by compact chemical assisted RO plants, and a detailed survey based on on – field continue monitoring and numerical models, aimed to select the optimal withdrawal location, timing and conditions, and to estimate the required restoration time.

**Key words:** eutrophication, phosphorus removal, lake recovery, reverse osmosis (RO)

## 1 Introduction

The Shichahai lakes area is located in the center of the town of Beijing, close to the Forbidden City, and consists of the Xihai, Houhai and Qianhai lakes (Fig. 1). The water area is 33.6 hectares (not including the Beihai, Zhonghai and Nanhai), and is part of a river network, anciently known as “the imperial water network”, that derives waters from the Miyun Reservoir by the following path: Miyun Reservoir—Beijing—Miyuan canal—the Summer Palace—Beijing—Miyun canal (beginning to flow in different direction from the Maizhong bridge)—Xihai—Houhai—Qianhai.

The length of the Shichahai water system is 5.2 kilometers, the width on average is 0.29 kilometers, and the average water depth is 1.5 meters. The total volume of the Shichahai lakes system is around 600,000 m<sup>3</sup>.

Bibliographic findings on historical development of water supply in Beijing give evidences that in ancient time (1000 ~ 2000 B. C. ) Beijing had abundance of water coming from North West Mountains by several rivers and natural reservoirs. After 1200 (Shichahai lakes were built around 1270), the original water scheme of the town was integrated, mostly in south direction, with new canals and lakes around emperor residence, with the aim to satisfy the water requirements of the city.

In middle 1900 the water scheme inside Beijing was further integrated with new channels and

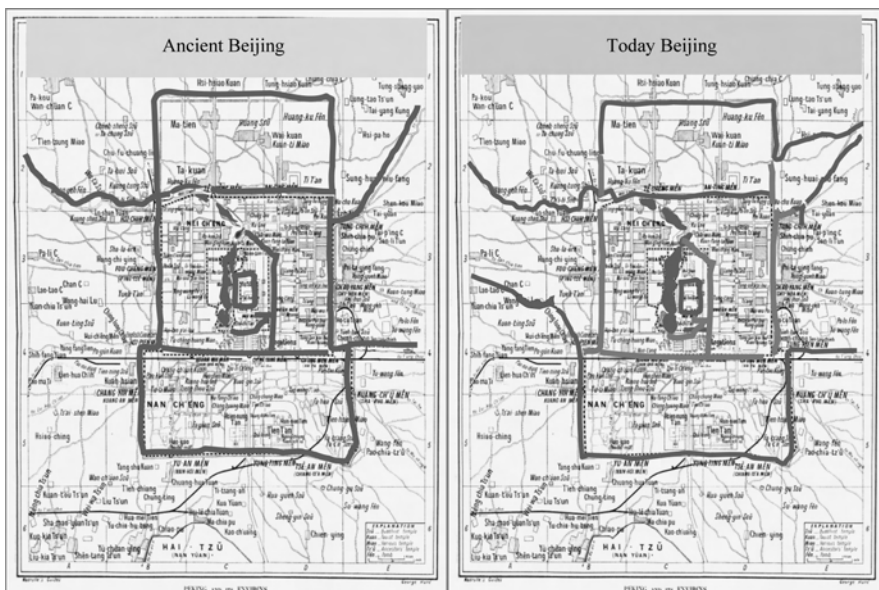


**Fig. 1 The Shichahai lakes system**

lakes mostly in the west side of the city but, in years around 1950 ~ 1960, most of the old channels, including the inflow and outflow connections of internal Lian Hua Lake, were buried and several changes were introduced in lakes profile (construction of banks, inflow gates and changes in deepness, which now is around 1.5 meters), that limited the circulation of water. But evidences of water circulation were still present until 1970; waters, assured by YongDing River and Miyun and Guanting Reservoirs fed the lakes and channels situated around ancient city, while the outgoing waters from Shichahai were diverted to “Golden River” (in front of the present Tian An Men square) and than to the “south moat” channel situated in the south of the ancient city.

After 1970, a drought caused the shortage of water supply from the YongDing river; consequently the Miyun and Guanting Reservoirs became the main sources of the water network scheme. In addition, other channels were buried after 1990, causing a further reduction of the circulation of water in the lakes. Fig. 2 presents a comparison of the water network as it was and as it is today (the buried canals are highlighted in green).

At present, the reduction of the inflow due mainly to upstream water scarcity, the increase of pollution discharged into water bodies and the closure of the outflow of the system have dramatically compromised the equilibrium of the lakes system. Moreover, from a water management perspective, the need to optimize the scarce water resources with many different objectives progressively transformed the Shichahai lakes into a completely artificially controlled hydraulic system, that is presently conducted by a policy based on short pulse feeding operations of polluted external waters carried out with the goal to restore the required water levels within certain predefined intervals, without any awareness of the consequences for the water quality level in general and the trophic state in particular.



**Fig. 2 Ancient and present water networks of Beijing compared**

## 2 Preliminary survey and study

In 2005 the Sino – Italian Cooperation Program, supported by the Italian Ministry for Environment and Territory (IMET) and the Beijing Environmental Protection Bureau (EPB), financed a study to identify the causes of the current degradation of the lakes and define cost effective solutions. A numerical model was constructed in order to understand the hydrodynamic and chemical state of the system, and some analyses were carried out to assess the general level of pollution of the water, as well as the composition of bottom sediments. A summary of the main acquired data about water quality is shown in Table 1. In synthesis, these studies demonstrated that a series of joined causes are responsible of the deterioration of the water quality of the whole system;

(1) The almost null water circulation reduces the amount of re – oxidation of the lake water and the exchanges between different parts of the lakes favoring the degradation of particularly solicited sub – areas;

(2) The pulse feeding of the lakes system with polluted waters causes the progressive accumulation of a significant amount of organic sediments particularly rich in solids bounded nutrients (N and P in various chemical forms) and a continuous varying composition of the lake water pollutants;

(3) The significant external and internal load of nutrients is responsible of a trophic state classifiable in the range of eutrophication, with a high risk of excess growth of algae causing de – oxygenation of waters with several negative consequences so as turbidity, absence of fish, periodic algal blooms, green colored waters, mucilage formation etc.

As a consequence, the water quality parameters in Shichahai are between grades III and IV of the Chinese environmental quality standard for surface water, with the exception of ammonia and total N and total P that don't comply even with the worst grade V standards. The Chinese standards for surface water bodies are unified for rivers, streams and lakes, with the only exception for P, whose limit is reduced for lakes and reservoirs to the stricter value of 0.05 (Grade III, IV and V), 0.025 mg/L (Grade II) or 0.01 mg/L(Grade I).

**Table 1 Water quality data acquired during the preliminary survey campaign**

Lake	Date	TDS (mg/L)	TSS (mg/L)	TN (mg/L)	TP (mg/L)	BOD <sub>5</sub> (mg O <sub>2</sub> /L)	Chlo - A (µgr/L)	Temp. (°C)
Xihai	Means	242.3	4.8	1.8	0.084	5.7	19.6	16.0
	of 8							
	01/11/06	268.8	11.0	6.8	0.148	5.1	3.8	14.5
	values							
	15/11/06	256.5	3.7	3.3	0.150	5.5	32.1	9.3
	15/03/07	731.9	12.8	13.0	0.112	8.7	58.9	7.7
	Mean	374.8	8.1	6.2	0.123	6.3	28.6	11.9
Houhai	Means	256.7	8.5	1.4	0.111	5.5	17.5	16.5
	of 10							
	02/11/06	286.2	4.7	4.7	0.107	5.2	2.1	14.5
	values							
	16/11/06	262.5	11.7	3.3	0.141	8.4	44.2	14.9
	16/03/07	656.0	11.0	12.3	0.063	8.3	44.7	7.5
	mean	365.4	9.0	5.4	0.106	6.8	27.1	13.3
Qianhai	- means	245.9	6.3	1.4	0.057	5.5	15.8	16.5
	of 10							
	03/11/06	268.4	2.7	3.3	0.074	4.7	4.9	14.5
	values							
	17/11/06	264.3	11.4	3.1	0.117	8.4	35.4	14.5
	17/03/07	633.1	7.5	11.7	0.074	8.2	32.3	8.8
	mean	352.9	7.0	4.9	0.080	6.7	22.1	13.6
Means of all the data		364.4	8.0	5.5	0.103	6.6	26.0	12.9

### 3 Evaluation of the present trophic state of the lakes

The most evident aspect of the Shichahai lakes is the general low aesthetical quality of waters, due to green coloring, excess algal biomass and turbidity, specially in some particularly solicited spots, clearly due to the phenomenon of eutrophication.

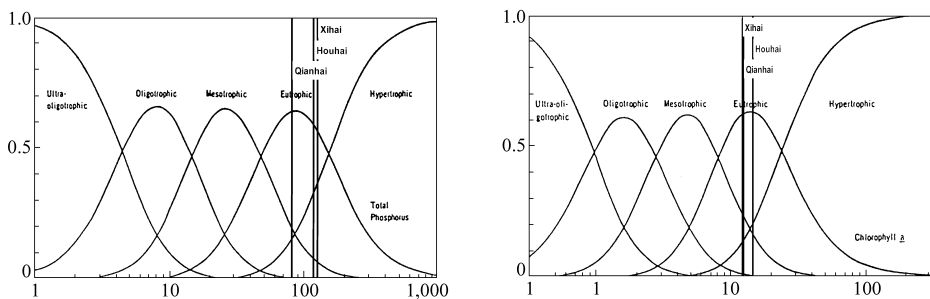
Eutrophication is a particular form of de - oxygenation pollution due to extraordinary growth of algae, that happens in lakes and water bodies characterized by high retention times, often emphasized in presence of shallow waters. The main cause of eutrophication is the accumulation of nutrients (mainly N and P) that, discharged into the lake by point (civil and industrial sewers) and non - point (mainly agriculture and stockbreeding) pollution sources are trapped into the food chain of the lake ecosystem and mainly stored in particulate organic form into the benthonic sediments at the bottom of the lake. Because eutrophication is a chronic form of pollution, its effects appear after years or decades of continuous accumulation of the nutrients coming from the pollution sources of the basin (external load) into the benthonic sediments (internal load) (Provini and Premazzi, 1984).

The first measure to control eutrophication is the reduction of the external loads of nutrients. This measure is to be possibly applied before the manifestation of the symptoms. When the symptoms are evident it is necessary to both reduce the external loads and remove the internal loads.

To evaluate the consistency of the internal load some parameters are usually taken into consideration; particularly the concentrations of the various forms of N and P in the water, but also the concentration of Chlorophyll (as an indicator of the presence of algae) and the turbidity. A largely internationally accepted scale to evaluate the trophic state of a lake is the OECD scale (Vollenweider & Kerekes, 1982) that compares the mean annual concentrations of total P and Chlorophyll - A with statistical distributions of many previously evaluated cases.

A preliminary evaluation of the trophic state of the Shichahai lakes can hence be performed by comparing the mean concentrations of P and Chlorophyll - A measured in the lakes during the first phase survey (Table 1) with the OECD distribution graphs. The comparison for both the parameters is presented in Fig. 3, showing that all the three lakes are in the center of the eutrophication frequency distribution both for P and Chlorophyll.





**Fig. 3** Classification of Shichahai lakes by comparison with probability distribution of trophic classes based on total P and Chlorophyll – A annual means ( Based on Vollenweider R. , Kerekes J. , 1982)

A second important aspect concerns the comparison between the two nutrients involved, N and P. The Liebig principle states that for algae growth, constant ratios among C, N and P are required. For this reason, excluding the C that is easy available in various forms (including the atmospheric  $\text{CO}_2$ ), a comparison between N and P allows to select the so – called limiting factor, that, in most cases, is represented by P. The knowledge of the limiting factor is very important, because the simplest way to reduce the algae growth is an intervention aimed to reduce the limiting factor. Even if further studies defined that the removal of the lone limiting factor can cause dystrophic situations with modifications of the lake ecosystem (for example with the emergence of N – fixing algae) it is undoubted that the fastest effects of a recovery are obtainable by the reduction of the limiting factor.

The selection of the limiting factor can be performed again on the base of the OECD suggested ranges for the selection of the ratios between the two nutrients (Vollenweider & Kerekes, 1982), that are as follows:

$\text{N} - \text{inorg}/\text{P} - \text{ortho} < 10 \rightarrow \text{NITROGEN LIMITATION}$      $\text{N} - \text{inorg}/\text{P} - \text{ortho} > 18 \rightarrow \text{PHOSPHORUS LIMITATION}$

The calculated ratios for the data of the first phase survey of the Shichahai lakes are the followings:

Xihai: 31.1    Houhai: 26.0    Qinhai: 31.3

Because all the three ratios are much higher than the suggested limits, it can be concluded that all the three lakes are strongly phosphorus limited. This means that P is the main pollutant to study, because its removal will give the maximum benefits in terms of eutrophication control. Of course the above described reasons imply that also the N should be reduced, but the first effects of the recovery intervention will be observed when the limiting factor (P) will start to decrease significantly.

These considerations imply that the rehabilitation campaign should dedicate its efforts to obtain a general increase of all the water quality parameters with particular reference to total and ammonia nitrogen (that seems to exceed the standards more than other parameters) and a special attention to reduce the trophic state from the present “Eutrophication” level (see Fig. 3) to a more acceptable mesotrophic or oligotrophic level.

On this base, the first phase study evaluated possible actions to remediate pollution using the model and defined the next steps for the selection of the most appropriate methods to pursue the final restoration of the Shichahai system. Based on these results, the following milestones can be posed for the continuation of the pollution assessment and rehabilitation campaign;

(1) The most problematic aspects of the pollution of the lakes are related to the present trophic state classifiable as eutrophic; the turbidity and green color that the waters of the lakes present for most part of the year and the compliance with the Chinese surface water standards;

(2) The rehabilitation process should be implemented so as to obtain a continuous and stable improvement of the general characteristics of the lakes with a duration of the campaign to be evaluated in the next phase;

(3) Considering that the lakes form a basically artificial hydraulic system totally controlled by regulation weirs and gates and fed by a very large, complex and polluted external hydraulic system, a control of the external load of nutrients will be a very difficult challenge. For this reason alternative scenarios will be defined with the goals to ① control the external nutrients load so as to maintain the good quality reached at the end of the rehabilitation programme; ② implement a permanent system of “pump and treat” plants aimed to continuously remove nutrients and pollutants from the water of the lakes so as to balance the nutrients and pollutants continuously fed by the external water system; ③ a combination of scenarios ① and ②;

(4) The rehabilitation process should include actions to reach an improvement of the most visible water quality features in the most solicited parts of the lakes with symptomatic actions like bubbling and hypolimnetic aeration, removal of algal matter and/or organic pollutants and general water vivification by inducing advective currents in the lakes water.

On these bases, the next phase will focus on the development of a pilot project consisting in the construction of a “pump and treat” pilot treatment plant in the Houhai lake, the upgrade of the monitoring network over the entire Shichahai system and the further development of the initiated environmental restoration plan.

The data collected by the monitoring system will allow a complete comprehension of the real processes within the system and monitor the impact of the newly installed pilot treatment plant.

#### **4 The proposed solution: hypolimnetic water pumping and treating**

The standard way to treat lake eutrophication problems involves that all the discharges of nutrient polluted water in the basin of the lake should be treated with specific WWTPs. This approach cannot presently be tackled for the Shichahai lakes, because all the external nutrient loads come from a very large and polluted external water system where hundreds of single discharges would require strict treatment. Moreover the lakes are already eutrophic at present, and require a removal of the internal loads that were stored in the lake sediments in years.

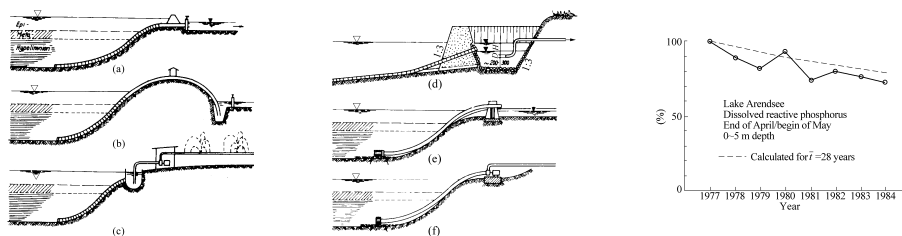
The removal of internal loads can be pursued by dredging the bottom sediments, but this solution is expensive and environmentally unfriendly (destruction of bottom ecosystem, turbidity problems during the removal works, problems for the disposal of the dredged polluted sediments).

For these reasons a different approach was selected, that allows both the removal of internal loads and the stabilization of the reached trophic condition after the initial transition from the eutrophic state. The selected approach involves the continuous removal of soluble and particulate nutrients from the lakes waters. As explained before, the internal loads are mainly stored in the sediments in particulate form but, thanks to benthonic metabolic processes that happens at variable rates as a function of the seasonal weather variations, they are recycled in the waters in soluble and particulate form. Particularly in summer, high concentration of soluble N and P are often observed in the hypolimnetic waters, due to the stratification of the lake caused by significant temperature gradients along the depth and a particularly effective activity of the benthonic biochemical processes due to the high temperature. For this reason the selected discharge of hypolimnetic water is an interesting approach to reduce the internal loads. Fig. 4 shows the proposed technologies and the results of the application of this policy for the restoration of the lake Arendsees; in that case the hypolimnetic waters were withdrawn and used for agricultural irrigation with beneficial effects of the high nutrients concentrations.

This approach cannot be followed for the Shichahai lakes because the present water scarcity situation requires that a minimal amount of water should be pumped out of the lake; but the withdrawal of hypolimnetic water is a very interesting method to feed a treatment plant with high P and N concentration water.

This method will require one or more plants to withdraw water from selected spots of the lake presenting the maximum P and N concentrations (hypolimnetic waters), treat them with very high efficiency and return them to the lake. The selection of the optimal withdrawal points, the experimentation of the treatment method by an on – site real scale treatment plant and the evaluation

of the duration of the recovery campaign will be defined in the phase 2 experimentation.



**Fig. 4 Selected discharge of hypolimnetic water; proposed technologies (left) and decrease in P concentration as a result of the application of the policy (right) (Uhlmann & Klapper, 1985)**

## 5 The phase 2 experimentation

The next phase of the experimentation will aim to test several different and very important issues so as to give an answer to the following important questions:

(1) Will a “pump and treat” approach be enough to reach, without significant interventions on the loads fed to the lakes from the external polluted water system, a stable good pollution level within the lakes?

(2) How long is the rehabilitation process going to last by this approach?

(3) How many plants will be required to optimize the process?

(4) What will be the most appropriate and cost effective treatments to obtain the above mentioned goals?

(5) What policies will be most effectively applied to obtain the goals (continuous or pulse treatments; selections of optimal collection and restitution points; optimization of the level of water treatment)?

(6) Will the oxygen saturation of treated water in conjunction with an aware selection of the restitution point an effective alternative to the more traditional hypolimnetic aeration by bubbling to obtain an immediate increase of the general water quality level in the most visible parts of the lakes?

Basically, these points will be tackled with three parallel activities;

(1) An experimentation conducted by a real scale on-site treatment plant that will identify conduction policies and problems, real scale reachable efficiency, real scale conduction and maintenance costs;

(2) A one year survey and monitoring campaign to obtain a detailed knowledge of the trophic state in particular and the main pollution parameters that affect the lakes in general;

(3) A numerical modeling effort to evaluate the hydrodynamic conditions, the fate of the most significant pollution parameters of the lakes in general and the trophic state in particular.

These three activities are described in the following paragraphs.

### 5.1 The chemical assisted RO pilot treatment plant

The most used technique for phosphorus removal in wastewater treatment plants includes a coagulation – flocculation followed by a settling tank. But for low P and TSS concentrations a more compact contact filtration (coagulation – flocculation – sand filtration) can reach even better efficiencies in less space and with reduced production of backwashing sludges (Böller, 1985). In the case of surface water treatment, this technique can be effective especially in the case of a significant presence of organic particulate form. As already described, this can happen in specific climatic and benthos activity conditions. In other circumstances, the main form of P is the soluble orthophosphate, that cannot be effectively treated with concentrations lower than about 0.5 mg/L.

For the situation of low concentration P treatment, the membrane technologies have been most recently considered of growing interest. A recent 3 day national Water Environment Research Foundation (WERF) workshop on achieving low effluent nutrient levels devoted an entire session to this topic (Strom, 2006) demonstrating that, in addition to removing the P in the TSS, membranes also can effectively remove dissolved P. Specifically, reverse osmosis (RO) systems have all been used in full – scale plants with good results. Reardon (2006) suggested a value of 0.008 mg/L as the current reliable limit of the technology. Furthermore, chemical techniques can even increase the RO membranes efficiency and improve the general conduction conditions (fouling reduction, increased brine concentration, optimization of transmembrane pressure).

To pursue all these goals, the pilot plant has been designed by a multi – purpose scheme that includes several treatment stages (chlorination, assisted filtration, adsorption and reverse osmosis) to be tested together. Specifically, the plant includes the following treatments:

Lake water will be taken by the vertical – axis pumps installed in the suction well and conveyed to the filters;

Prior to filtration, hypochlorite, flocculants, poly – electrolytes could be added when required; A 10 percent solution of sodium hypochlorite will be used to bring down the observed levels of ammonia;

The flocculant (ferric chloride) will induce the flocculation of colloidal solids to be removed especially with pH values near or above 8, and the formation of settleable iron phosphates to be removed by filtration;

Finally, the polyelectrolyte will act as a stabilizer to facilitate the flocculation;

A mixer will allow the perfect coagulation of all the sequentially added reagents;

The sand and activated carbon filtration system has been designed as a testing base to gain knowledge to be used to plan the next steps. Specifically, this section has been arranged to allow maximum flexibility by ways of pneumatic valves that allow the operators to; (a) accomplish the filtering by single filter excluding the other; (b) use the two filters in sequence or; (c) simultaneously, as the water is apportioned between the two filters. Also, oxygen could be fed into the water by aeration, to test a possible improvement of the filtration efficiency;

The outlet 10 L/s flow will be separated in two streams, to allow the further reverse osmosis stage for a flow – rate of 5 L/s. Therefore, the total discharge into the lake will vary from 5 L/s to 10 L/s depending on the tested options that will guide the future choices. To have an idea of the reachable effects, a continuous treatment of 10 L/s will treat all the water of the three lakes (600,000 m<sup>3</sup>) in less than two years, while three plants will treat the whole volume in about 7 months;

For the reverse osmosis stage; in order to avoid the “scalant effect” on the membranes and to balance the pH levels of the water to be discharged into the lake, a 9% solution of hydrochloric acid will be added.

Treated water will then be aerated by an ejectors system and brought to the discharging system. The aeration of the effluent is aimed to obtain aerobic conditions in proximity of the outlet, so as to increase nitrification and reduce P solubilization, with an approach similar to the hypolimnetic aeration.

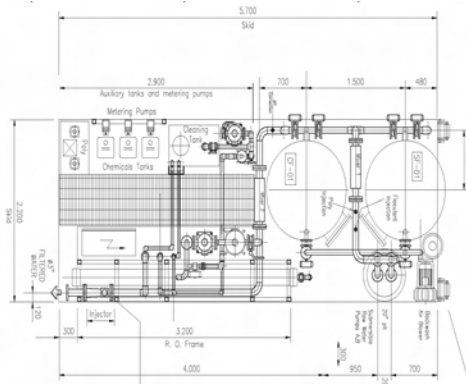
The brine (with a flow rate of 1 L/s) will be dumped into the sewer system. A detailed plan of the pilot plant is shown in Fig. 5. The plant, that presents a very compact size, will be skid mounted to be easy movable and re – locatable. His architectural design, selected by local authorities among several solutions, includes a suggestive external translucent cladding with an internal neon lighting (Fig. 6).

## 5.2 The planned continuous monitoring campaign

A water monitoring campaign will be conducted throughout the project duration to study the water chemical and physical parameters (BOD, COD, TDS, TSS, Ammonia N, Nitrate, Phosphate and Dissolved Oxygen).

The campaign will be conducted by multiparametric probes and automatic analyzers, with some confirmation laboratory tests. Particularly, a specific campaign will be conducted in summer to evaluate the hypolimnic concentrations of phosphates and nitrates.

Also the sediments will be analyzed for nutrients (TP, TN,  $\text{NO}_2 - \text{N} + \text{NO}_3 - \text{N}$ ) and for Carbon (DOC), and a detailed investigation of the sediment thickness will be conducted in the three lakes in order to evaluate the potential quantity of nutrient that could be taken part in the chemical reaction in the interface water – sediments.



**Fig. 5 Detailed internal plan of the pilot plant**



**Fig. 6 Rendering of the external architectural design of the plant**

### 5.3 Hydrodynamic and trophic state numerical modeling

The data acquired in the monitoring campaign will be used to calibrate two specific numerical models: The first will be a detailed hydrodynamic model that will allow to assess the vivification status in all the parts of the three lakes. This model will be 2D based on a 30 m × 30 m horizontal mesh, and will include the modeling of some conservative concentration parameters. The second model will be a quasi 3d model of the trophic state. The CE – Qual – W2 model will be calibrated and used to evaluate the different possible policies to be compared for most efficient recovery activity.

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# Connotation of Healthy Life of Yellow River Based on Theory of Dissipative Structure

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**Abstract:** This paper uses theory of dissipative structure originated from the No. 2 principle of thermodynamics to analyze connotation of healthy life of the Yellow River. According to I. Prigogine's theory, there must be at least four requirements to form and sustain a dissipative structure. First, the system must be open, neither an isolated system nor a closed one can produce a dissipative system. Second, the system must locate in the non-linear area far away from equilibrium, and a dissipative structure is a kind of "live" and ordered one. Third, there should exist some non-linear dynamic processes in the system, such as a positive or negative feedback mechanism and so on. And the last, the system can be harmonious and be in order through interaction of fluctuation between function and structure. Based on analysis of the Yellow River according to the four conditions above-mentioned, a conclusion made that the river meets the demands of a dissipative structure. And form of entropy change and expression of total entropy of healthy life of the Yellow River are derived, and a conclusion is made that increasing negative entropy flow is the fundamental approach to sustain healthy life of the Yellow River. To sustain healthy life of the river, more measures should be taken to increase negative entropy flow, to expand exchange of matter and energy between the original system and the surroundings, and to realize dissipation of matter and energy to the utmost extent; which can result in a systemic structure to sustain the healthy life of the river. In order to ensure evolution of the river in ordered direction, measures in accordance with subsystems of the river should be taken to turn it to be an ordered dissipative structure of self-organization in time, space and function.

**Key words:** the theory of dissipative structure, an open system, entropy, negative entropy flow, healthy life of the Yellow River

## 1 Introduction

The theory of Dissipative Structure is a new methodology that raised in 1970s (I. Prigogine, 2005), it is developed based on the No. 2 principle of thermodynamics in physics. I. Prigogine, a famous physicist of Belgium, pointed out that an open system far away from balance, such as mechanical, physical, chemic, biologic, social and economical system, will turn into a self-organization through exchanging energy and molecules with surroundings endlessly when external conditions reached certain threshold value, accordingly, quantitative change leads to qualitative change. The subsystems composing the whole will act to coordinate each other, which makes it possible that the system will become an ordered structure in time, space and function from primary unordered state. The new ordered structure in nonequilibrium state is named as dissipative structure (Zhang Ken hua et al., 1998).

## 2 The Yellow River is a dissipative structure

According to I. Prigogine's theory (Nicolis et al., 1986), there should be at least four requirements to form and sustain a dissipative structure. First, the system must be open, neither an

isolated system nor a closed one can produce a dissipative system. Second, the system must locate in the non – linear area far away from equilibrium, and a dissipative structure is a kind of “live” and ordered one. Third, there should exist some non – linear dynamic processes in the system, such as a positive or negative feedback mechanism and so on. And the last, the system can be harmonious and be in order through interaction of fluctuation between function and structure. This paper indicates that the Yellow River is a dissipative structure on the basis of analysis of the Yellow River.

## 2.1 The Yellow River is a complicated open system

In physics, thermodynamics and mechanics, a research object is regarded as a system, and each system matches a corresponding theory respectively. According to interaction extent of system and surroundings, the system is classified into three patterns, namely, an isolated system, a closed system and an open system. Characteristics and state of the three kinds of systems is presented in Table 1.

**Table 1 Characteristics and state of the three systems**

System name	Representation characteristics	System state
Isolated system	Neither energy nor matter exchange between system and environment	Ideal system
Closed system	Energy exchange but no matter between system and environment	Tradition system
Open system	Energy, matter and information exchange between system and environment	Complicated behavioral system

Strictly speaking, an isolated system does not exist in reality because a system always has various relationships and interaction with its surroundings, and surroundings have an influence on the system. Not effected by surroundings, process generated in an isolated system is spontaneous. Nevertheless, an open system is ubiquitous in reality. Both a closed and an open systems have been influenced by surroundings, and processes generated in the systems are quite different from an isolated one.

Obviously, the Yellow River is neither an isolated system nor a closed one, reversely, it is a complicated open system in fact. During the process of flow, it exchanges matter, energy and information with surroundings. Water on the earth and in oceans absorbs solar radiant energy, then, transforms it into potential energy. And the water overcomes  $G - force$  to vaporize itself into atmosphere moisture, then, it turns back to the earth as rainfall and the partial becomes water flow because of  $G - force$ , and the potential energy is lost partly in the process of raining, which turns into kinetic energy of river flow (Li Guoying, 2005). At the same time, river water that partial kinetic energy is stored in it flows endlessly from headstream to downstream. The energy of river water is consumed gradually because it overcomes flow resistance, erodes riverbed and carries sediment. The river accepts current and sediment endlessly from main stream and tributaries, and consumes energy for overcoming various resistance. And during the process of flowing, potential energy and kinetic energy interchange reciprocally, moreover, the river exchanges moisture with surroundings through vaporizing, raining and seeping.

## 2.2 The Yellow River is a nonequilibrium ordered structure

Two kinds of ordered structures exist in the nature, the one is entitled as a “dead” ordered structure for it is formed in the context of equilibrium, and it can exist without any exchange of matter and energy. The other is a dissipation structure entitled as an “live” ordered structure because it depends on uninterrupted supply of matter and energy from surroundings (Xu Guobin et

al. , 2004). The Yellow River is a complicated open system and a nonequilibrium ordered structure because it exchanges various forms of matter with environment incessantly. Just as riverbed configuration, water flow, percentage of sediment and so on, the river is not only outcome of dynamic process in the nature but also a kind of process itself. The Yellow River behaves differently in different time in a long run, and it has spatial changes as well. Obviously, The Yellow River is a nonequilibrium and ordered structure in space, time and function.

### 2.3 There is non – linear interaction among subsystems of the Yellow River

Dissipation structure demands some processes of non – linear dynamics in the system. So – called non – linear feedback process means that the process itself is influenced by results of the process. It is the non – linear interaction that leads to coordination among elements in the system. Accordingly, an ordered structure comes into being. The Yellow River consists of many subsystems, for instance, the subsystem of water cycle composed of many elements such as rainfall, seepage, runoff, evaporation and so on, the subsystem of sediment which elements are water and soil loss, silting, erosion and shaping riverbed and so on, the negative feedback to river way originating from forming of the delta in the Yellow River debouchments area. The subsystems are elements forming an ordered structure of the Yellow River, and there exist non – linear interactions which produces domino effect and coordination among them. In this way, the system becomes ordered from the disorderly. The interactions among the subsystems can not be described by linearity, on the contrary, , they are usually non – linear coupling ones in integration action of some subsystems.

### 2.4 The Yellow River achieves ordered harmony through fluctuation of structure and function

The Yellow River has fluctuations, and it is influenced by artificial or physical factors of surroundings. Consequently, runoff of the river appears changeable, which results in disproportionate distribution of percentage of sediment and bed configuration in space. Thune, innumerable “little fluctuation” emerges, and the river achieves ordered harmony. When fluctuation reaches certain extent, the river system will produce “huge fluctuation” and jumps to other state from the current.

## 3 Connotation of healthy life of the Yellow River based on theory of dissipative structure

### 3.1 Form of entropy change of the Yellow River

In the theory of dissipative structure, I. Prigogine has introduced concept of entropy to explain how a system interacts with surroundings and leads to an ordered system from the disorderly. Entropy is a measurement of ordering degree of a system in thermodynamics, and the bigger the entropy is, the higher the ordering degree of system is. Any entropy change in a system is composed of two parts (Li Rusheng, 1986).

$$dS = d_e S + d_i S \quad (1)$$

In Eq. (1),  $d_e S$  is entropy change due to exchange of matter and energy between a system and surroundings, and it is entitled as entropy flow. Its value is positive, negative or zero. The  $d_i S$  is entropy change due to nonreversible process of a system by itself, and it is named as entropy generation. Its value is always positive. Value of  $d_e S$ , entropy flow of an open system, is positive, negative or zero, and forms of entropy change are presented in Table 2. When gross entropy is positive ( $dS \geq 0$ ), which implies that negative entropy flow can not counteract entropy generation or environment supplies positive entropy flow, the nonreversible process of the system will not go on and the system will disintegrate finally. The Yellow River is an open system. Due to some artificial or natural factors such as excessive water utilization, water pollution, water and soil loss and so on, problems of silting, breaking off, flooding, drought will emerge. If those problems do not be



covered to produce enough negative entropy flow in the system, it is very difficult that to sustain healthy life of the Yellow River when gross entropy increases to maximum leading the system to collapse.

**Table 2 Gross entropy forms of an open system**

Gross entropy $dS$	Formula of Entropy	Process of system evolvment
$dS > 0$	$d_i S > -d_e S$	Gross entropy increases uninterrupted and collapse finally
$dS = 0$	$d_i S = -d_e S$	Negative entropy flow counteracts entropy generation and system locates in ordered state
$dS < 0$	$d_i S < -d_e S$	Negative entropy flow supply is sufficient, and system evolves in ordered direction through self – organization

### 3.2 The gross entropy expression of healthy life of the Yellow River

Table 2 shows that it is necessary to maintain healthy life of an open system that the system holds enough entropy flow, absolute value of which is enough to counteract entropy generation originated from nonreversible process of the system itself. Thus, the system reaches an ordered state from the disorderly. Only when Eq. (2) exists, can healthy life of the Yellow River be sustained. In the other words, the Yellow River need obtain energy and matter from surroundings uninterruptedly, then circulate and convert it inside the system, finally dissipates it gradually to sustain the healthy life of the Yellow River.

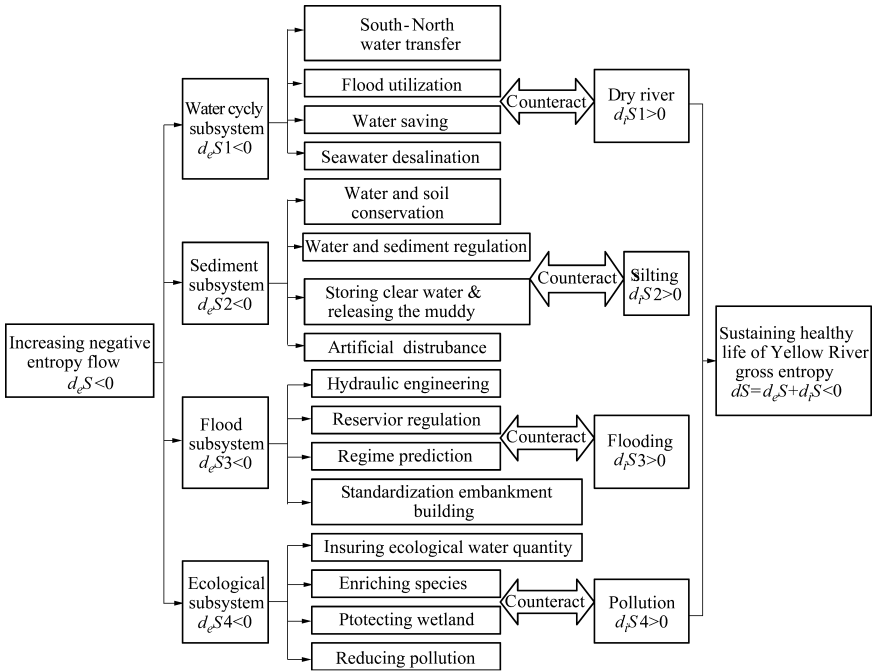
$$dS = d_e S + d_i S < 0 \quad (2)$$

According to No. 1 principle of thermodynamics, a creature always increases entropy ( $d_i S$ ) uninterruptedly, and it will end when the entropy achieves to maximum. The theory of dissipative structure indicates that an organism can emerge and exist from the disorderly to the ordered due to uninterrupted negative entropy flow ( $d_e S$ ) supply from exchange of energy and matter between the system and the surroundings. From the perspective of the theory of dissipative structure, it is necessary to sustain the healthy life of the Yellow River that introducing more negative entropy flow to reduce the gross entropy. Consequently, the system will be ordered and be in benign circle.

### 3.3 It is Fundamental to sustain healthy life of the Yellow River to increase negative entropy

According to the theory of dissipative structure, negative entropy is a measurement of systematization and it is also an indicator to value orderliness of a system or efficiency of energy conversion (Nicolis & Prigogine, 1977). The bigger the value is, the higher efficiency of a system is. To sustain the healthy life of the Yellow River, the measures increasing negative entropy should be adopted, which will increase exchange of energy and matter between the original system and the surroundings, and will dissipate matter and energy to the utmost extent. Accordingly, the system structure of healthy Yellow River can be formed and be sustained, and it will be ordered in time, space and function. Thus, maximum benefits of economy, ecology and society will be obtained.

As Fig. 1 shows, there are some subsystems in the system of the Yellow River, and each subsystem has entropy generation due to its irreversibility. A series of approaches should be adopted to increase negative entropy of each subsystem, accordingly, to strengthen exchange of matter and energy between the system and the surroundings. Then absolute value of negative entropy of each subsystem is bigger than entropy change of system itself, accordingly, the gross entropy is negative. As a result, life of the Yellow River is healthy and ordered.



**Fig. 1 Measures of increasing negative entropy to sustain healthy life of Yellow River**

In order to prevent water shortage and dry river due to too high value of  $d_i S_1$  in water cycle subsystem, approaches should be adopted to increase exchange of matter and energy between the subsystem and surroundings, such as South – North Water Transfer, flood utilization, water saving, sea water desalination and so on. Thus, the subsystem can produce enough negative entropy  $d_e S_1$  to counteract  $d_i S_1$ . To prevent riverway silted and first and second level perched river originating from too high value of  $d_i S_2$  in sediment subsystem, measures should be taken, such as water and soil conservation in the upstream, water and sediment regulation in the middle reach, artificial disturbance in the downstream, storing clear water and releasing the muddy in reservoirs. In the process, the system can produce enough negative entropy  $d_e S_2$  to counteract  $d_i S_2$ . To avoid flood, erosion and floodplain due to too high value of  $d_i S_3$  in flood subsystem, approaches should be adopted, such as hydraulic engineering, reservoir regulation, regime prediction, standardization embankment building in the downstream, thus, the system can produce enough negative entropy  $d_e S_3$  to counteract  $d_i S_3$ . And measures, such as insuring ecological water quantity, enriching species of wetland, protecting wetland and mitigating pollution, should be adopted to prevent water pollution, species reduction and wetland disappearance due to too high value of  $d_i S_4$  in ecological subsystem. Accordingly, the system can produce enough negative entropy  $d_e S_4$  to counteract  $d_i S_4$ . There exists non – linear interaction among the subsystems of the Yellow River. If the system meets the demands of Eq. (3), the subsystems can interact to reach an ordered self – organizational state in time, space and function.

$$dS = \sum_{n=1}^4 d_e S + \sum_{n=1}^4 d_i S < 0, \quad \left| \sum_{n=1}^4 d_e S \right| > \sum_{n=1}^4 d_i S \quad (3)$$

#### 4 Conclusions

Using the theory of dissipative structure, this paper explores the connotation of healthy life of

the Yellow River. Increasing negative entropy flow is the fundamental approach to sustain healthy life of the Yellow River. More measures should be taken to increase negative entropy flow, to expand exchange of matter and energy between the original system and the surroundings, and to realize dissipation of matter and energy to the utmost extent; which can result in a systemic structure. Consequently, the healthy life of the Yellow River will be sustained.

### Acknowledgements

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## Ecological Risk Value Assessment as Index of Water Quality (on Example of the Dnieper River)

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**Abstract:** In the paper the ecological risk assessment for Belarussian rivers with different degree of pollution is given. The method is based on a probability approach and uses Woodiwiss index. According to risk values the quality of river ecosystems in Belarus is quite high. In a site of a sewage discharge the risk probability runs up to 80% ~ 90%. In order to inter – calibrate index values for a comparative analysis between international, national, regional and basin levels a percentile principle of establishment of critical values of the Woodiwiss index equal to 25% was applied. A given approach has allowed more precisely to monitor probability of alterations in ecosystems and to reveal a possibility of further degradation at early stages. The risk assessment approach allows to display the reference sites. The use of them is recommended by the Water Frame Directive of the EU as one of general mechanisms of a comparative analysis of a water quality. The definition and use of risk probability values for river systems is an universal mechanism of determination and monitoring of a water quality and may be a tool for decisions making on a water resource management.

**Key words:** belarus, ecological risk assessment, woodiwiss index, river ecosystem, reference site

### 1 Introduction

Among numerous approaches to evaluation of a quality of surface waters the hydrological, hydrophysical, hydrochemical, biological and others are widely known.

It is understandable that determination of a polluting substance concentration does not answer a question of a state of water ecosystems. That is why a biological approach is of a great importance in a determination of a quality of surface waters.

An attempt of a development of a technique of water quality estimation using indicator hydrobionts was undertaken before in the 19th century yet and was based on a species composition of animals. A compilation of lists of “antagonistic hydrobionts” – species indicating “clear”, “polluted” and “transitional” waters has contributed in an application by Mez (Mez C. , 1898) of hydrobiological methods for a sanitary estimate of surface waters. The works of Mez were the basis for a development by Kolkwitz and Marsson (Kolkwitz R. , Marrson M. , 1908, 1909) of a classic system of indicator organisms, saprobionts for inhabitants of sewage waters, katabionts – for inhabitants of clear waters. Authors have distinguished 3 zones of contamination and compiled lists of indicator species attributed to each zone. On a basis of these lists a great number of methods have been developed (Knopp H. , 1954; 1955; Pantle E. , Buck H. , 1955) allowing to estimate the mean of saprobility of a biocoenosis and facilitating to understand results of a biological analysis by non – specialists. Zelinka and Marvan (Zelinka M. , Marvan P. , 1961) have introduced a concept of the saprobic valency. An application of the method was extended by Liebman (Liebman H. , 1962) and Sladeczek (Sladeczek V. , 1973). Now it is applied for a biological indication and classification of organic contamination of waters. Such approach is built on a principle of a significant transformation of a biotope and is applicable in more extent at significant concentrations of external reagents (ecological catastrophes). However a use of an invertebrate species composition is practically not applicable at a chronically low level of polluting substance.

Therefore a biological monitoring on a basis of indicator species may not be used always for practical purposes. In natural conditions an impact of contaminating reagents may not influence essentially, for instance, on a density of populatins of some species.

At present the indices of diversity applied in a population ecology (Shannon E. E. , 1948; Wilhm J. L. , Dorris T. C. , 1968) are used often in order to characterize a state of ecosystems. They are calculated taking into account the whole species composition of separate communities, for instance, a community of bottom hydrobionts for an assessment of a biota state in rivers.

The approaches proved to be very effective in which the ranging of studied systems is achieved on two and more parameters (for example, on species diversity and indicative values of indicator organisms). Examples of such systems may be the biotic index of the Trent River (TBI) (Woodiwiss F. S. , 1964) , index Verneaux and Tuffery (Verneaux J. , Tuffery A. , 1967) , Chandler (Chandler J. A. , 1970) and others.

At present the use of TBI for above – mentioned purposes is actual in connection with recommendations of the European Framework Water Directive.

A possibility to use of water invertebrates for a biomonitoring of freshwater ecosystems is conditioned by the fact that they constitute the most of species diversity of water – bodies, are the essential component of their self – purification and are characterized by multi – lateral ecological relations (Odum J. , 1975). In addition, a change of a state of the biotic component under an impact of an ecological system contamination is a direct indication of an ecological state of waters.

In spite of a general abundance of research and a number of international agreements in the field of surface water protection (for instance, European Framework Water Directive) , the unified methodical approaches to monitoring of freshwater ecosystems on a basis of a biotic component are not developed in Belarus till now. It concerns especially an ecological risk assessment (ERA). Analysis and assessment of ecological risks are effective especially, in particular, in those cases, when there are significant uncertainties in initial data on anthropogenic pressures on ecosystems and about the state of ecosystems; when reactions of ecosystems are not clear and have a character of a probability; when a way of a possible use of ecosystems in future assumes several alternative scenarios.

At such interpretation of the water quality assessment problem the application of the ERA methodology should be considered to be more efficient and organic than the use of traditional methodologies oriented to several established criteria (in particular, ambient water standart and others).

## 2 Method

The “Methods of a risk assessment arising at an impact of sources of pollution on water objects” (Aphanasiev S. , A. , Grodzinski M. D. , 2004) was used for the ERA. These “Methods…” was developed and approved when performing the PROON – GEF program of an ecological improving of the Dnieper River basin at the financial support of IDRC. The work was performed at territories of Belarus, Russia and Ukraine by specialists of these countries. These “Methods…” is the ERA instrument in river systems. It is a first step to a development of national ERA normative documents in countries of the Dnieper River basin on the unified methodological basis taking into account demands of the Directive 2000/60 EC.

The ERA process in water ecosystems differs in principle from traditional methods of a determination of the water ecosystem quality on a basis of a chemical pollution, physical or other anthropogenic pressures. The “Methods…” (Aphanasiev S. , A. , Grodzinski M. D. , 2004) is a version of “A framework for ERA; General Guidance” of the Canadian Council of Ministers of the Environment (A framework for… , 1996) to a specifics of problems arising at an assessment of an impact of pollution sources on water objects.

The most of successfully working ERA methodologies have a three – level structure: 1 – a test assessment; 2 – a preliminary quantitative ERA; 3 – a detail quantitative ERA (A framework for… 1996; EPA, 1993). Usually a performance of the first two levels is enough.

Test assessment is performed preferentially on a basis of an analysis of literary, reports, statistical and other materials. Questioning of experts working in a zone of a possible impact and data of a field protocol filled for each point are of a special importance. A main purpose of a test assessment is to establish or disprove an assumption that there is a risk of unfavourable changes for an ecosystem. It provides a basis for a conduction of the following stage – a preliminary quantitative assessment.

Preliminary quantitative assessment has an ultimate aim to obtain approximate assessments of unfavourable changes which may arise in ecosystems if these risks would be realized. Methods of obtaining of preliminary quantitative risk assessments may include the expert assessment of a probability and standard methods of the mathematical statistics.

A calculation method proceeds from the following assumptions (Grodzinski M. D., 1995). If a risk indicator  $x$  exceeds bounds of some given range of values with a possibility of unfavourable changes for an ecosystem, then a probability of such event (i. e. a risk) would be the less the range is wider; the risk indicator value  $x_i$  is farther of its bounds ( $x_{\max}$  and  $x_{\min}$ ); the less is variation of these values during a given time interval  $\Delta t$  or at a given area  $\Delta S$ . Proceeding from this, a probability of being of the risk indicator  $x$  values in bounds of a range of their permissible changes may be determined as:

$$q_x(\Delta t) = p(x_{\min} < x_i < x_{\max}) = \int_{x_{\min}}^{x_{\max}} f(x_i) dx_i \quad (1)$$

where:  $q_x(\Delta t)$  is probability of finding of the risk indicator  $x$  values in limits of a given norm during a time interval  $\Delta t$ ;  $x_{\min}$  and  $x_{\max}$  are upper and lower risk indicator  $x$  values limiting diapason of their ecologically permissible values;  $f(x)$  is a density of  $x$  distribution.

When there are no another hypothesis, distribution of the  $x_i$  indicator values could be assume as Gaussian (normal), than equation (1) may be determined as:

$$q_x = q(x_{\min} < x_i < x_{\max}) = \Phi\left(\frac{x_{\max} - \bar{x}}{\sigma_x}\right) - \Phi\left(\frac{x_{\min} - \bar{x}}{\sigma_x}\right) \quad (2)$$

where:  $\Phi$  is a function of a normal distribution, values of  $\Phi$  are taken from a manual of a mathematical statistics,  $\sigma_x$  is a mean quadratic deviation of the  $x$  value.

So a probability of an ecological risk  $x$  during a time interval  $\Delta t$  is estimated as:

$$p_x = 1 - q_x \quad (3)$$

This method of ERA is reliable when the  $x$  and  $\sigma_x$  values are assessed authentically enough. At the express – method of ERA it is possible to use instead of statistical values  $\bar{x}$  and  $\sigma_x$  their expert evaluations.

As a mean arithmetical value of  $x$  it is recommended to use its value measured in a site for which a risk is assessed. In order to substitute the  $\sigma_x$  it is possible to use its value calculated from selected values of the variable  $x$  measured in all probe sites (including the “hot” one) for a given river. In that case the  $\sigma_x$  value will prove to be over – estimated for all sites of sampling if compare to the “hot point” for which it will be under – estimated. Taking this into account, the  $\sigma_x$  values calculated for all sites of a given river should be corrected for each specific site. Values of a correction coefficient ( $k$ ) by which a “mean river”  $\sigma_x$  value should be divided, are given in Table 1.

**Table 1 The values of a correction coefficient ( $k$ ) for ERA calculation**

Distans from sewage discharge	Above discharge (Control)	Discharge	Below discharge. Up to:			
			1 km	3 km	5 km	15 km
$k$ coefficient	3.0	3.0	1.5	2.0	2.5	3.0

At present work, in frames of preliminary quantitative assessment a description of the algorithm of assessment and a calculation of a risk rise probability in most significant “hot points” of the

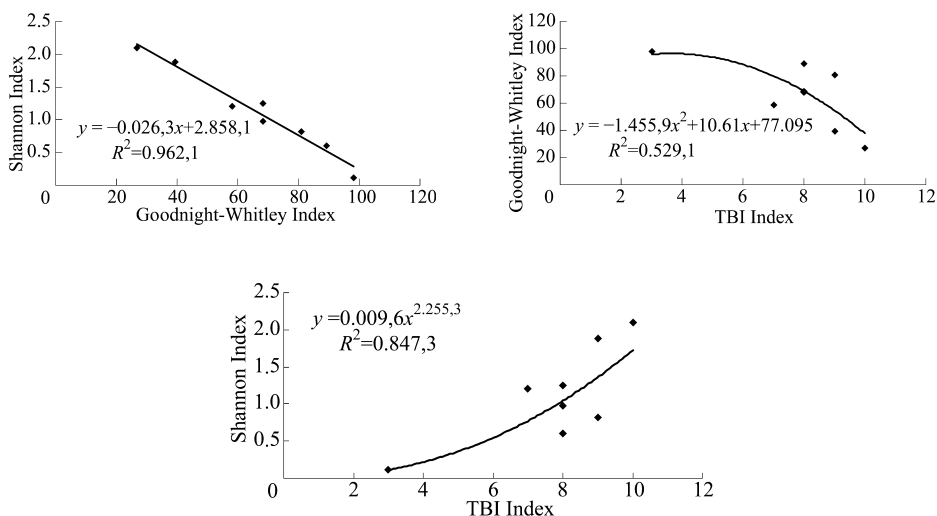
Dnieper River basin is given.

These assessments may be preliminary only. Nevertheless they are quite sufficient to analyze data on a source of contamination, to take a decision and to develop a general plan of actions on a liquidation of dangerous alterations in zones exposed to its influence. Such a practice of ERA is a research standard in most countries.

### 3 Results and discussion

#### 3.1 Correlation between biotic indices

We have studied a correlation between biotic indices used most often (Megarran E., 1992.; Semenchenko V. P., 2004) on an example of river and spring ecosystems. Values of the Shannon, Goodnight – Whitley and TBI indices for the river system Svisloch – Berezina are given in Fig. 1.



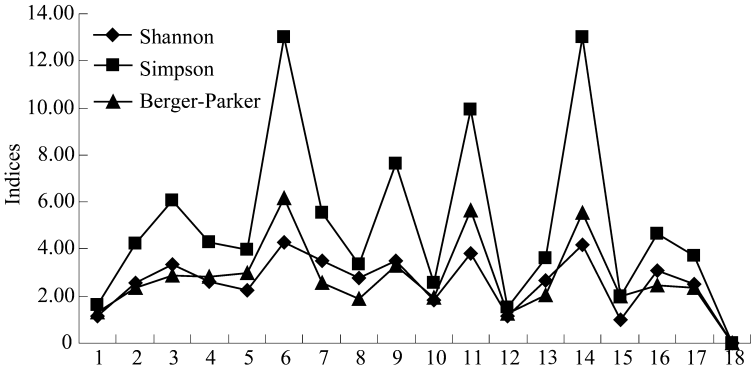
**Fig. 1 Relationship between Shannon, Goodnight – Whitley and TBI indices. Index values are calculated for the river system Svisloch – Berezina**

Relationship between the Shannon – TBI and Goodnight – Whitley indices is negative, between the Shannon and TBI ones is positive as it should be expected from a definition of these indices. Values of Shannon and TBI indices are increasing and those of Goodnight – Whitley are decreasing with an increase of a biological diversity.

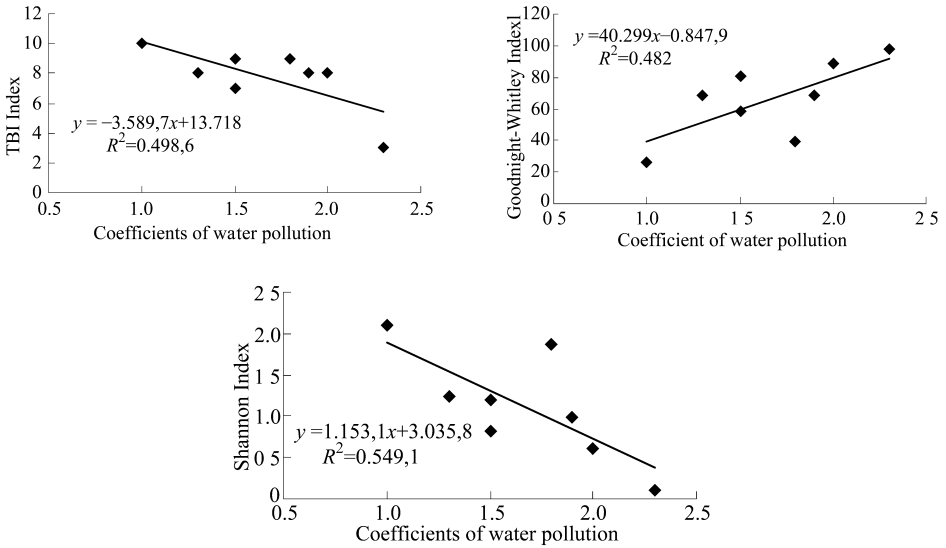
In Fig. 2 values of the Shannon, Simpson and Berger – Parker indices calculated for 19 springs of the National Park “Braslav Lakes” are given. It is seen that a dynamics of changes of all three indices is identical.

#### 3.2 Correlation between biotic indices and environmental factors.

We have done such an analysis for 8 sites of the river system Svisloch – Berezina using data on a contamination of water and bottom deposits by 15 heavy metals and for 17 sites of Dnieper, Berezina and Pripyat Rivers on data of water contamination (Figs. 3, 4, 5).



**Fig. 2** Values of the Shannon, Simpson and Berger – Parker indices calculated for 19 ( abscissas axis) springs of the National Park “Braslav Lakes”

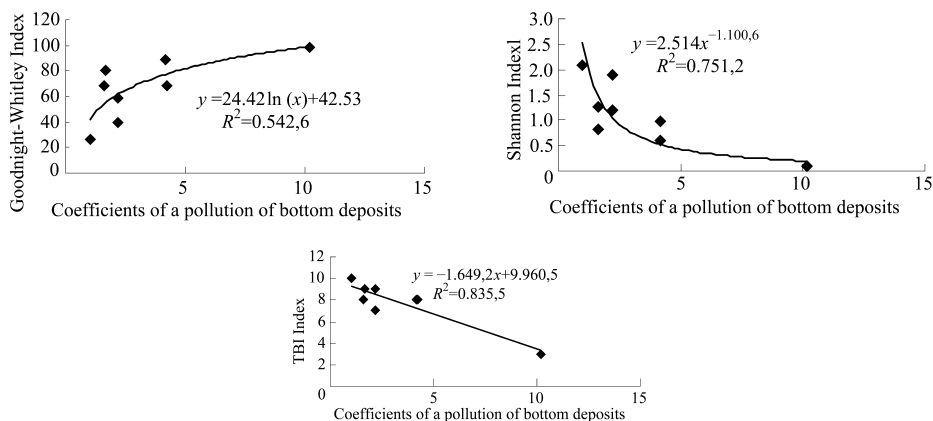


**Fig. 3** Relationship between biotic indices of sample stations and coefficients of water pollution by heavy metals ( a result of division of values at a single station by values at the cleanest station. Mean values for 15 heave metals) of the Svisloch – Berezina river system

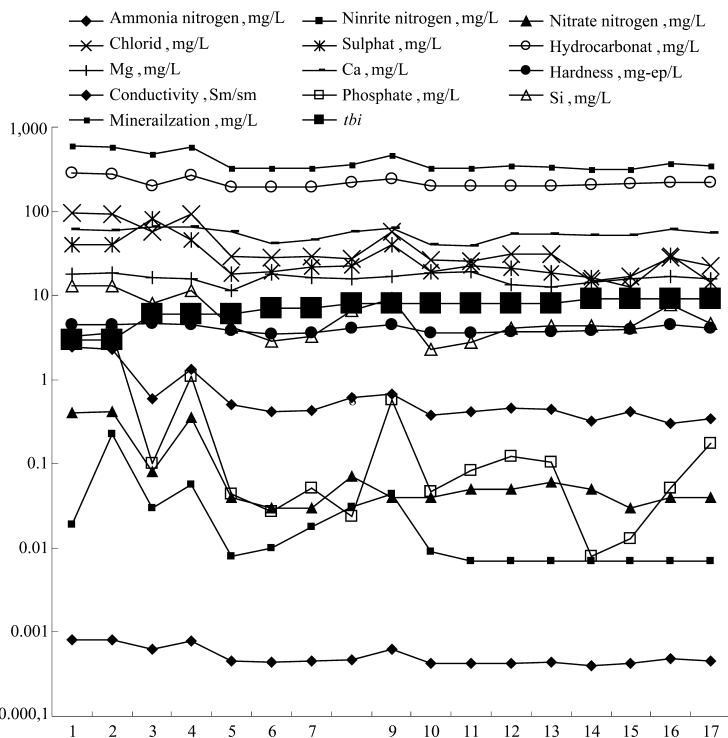
A tendency of a biotic index decrease with an increase of a concentration of pollutants including heavy metals and hydrochemical parameters in water and bottom deposits is evident from data available.

Dynamics of hydrochemical parameters and TBI according to sampling dates for 17 stations studied of Dnieper, Berezina and Pripyat Rivers are given in the Fig. 5.





**Fig. 4** Relationship between biotic indices of sample stations and coefficients of a pollution of bottom deposits by heavy metals ( a result of division of values at a single station by values at the cleanest station. Mean values for 15 heave metals ) of the Svisloch – Berezina river system



**Fig. 5** Dynamics of hydrochemical parameters according to sampling dates for 17 stations studied of Dnieper, Berezina and Pripyat Rivers. A logarithm of values is on the ordinates axis. Ranging of stations in relation to the TBI increase is on the abscissas axis

### 3.3 Ecological risk assessment

Further the TBI index (Woodiwiss, 1964; Metcalfe, 1989) was used for the ERA because it was adopted for the water quality assessment in Belarus and in accordance with the EFWD (Directive 2000/60/EC). This research has been performed at rivers of the Dnieper basin. The four "hot sites" has been analyzed. Samples were taken in different distances from sites of a sewage discharge of big towns: Gomel at the Sozh River, Retchitsa at the Dnieper River, Mozyr at the Pripyat River and Minsk at the Svisloch – Berezina river system. Hydrobiological samples were taken and a species composition was determined at each site. Values of the biotic index TBI were calculated on a basis of a species composition. These values have proved to be over 6 for "hot sites" of Mozyr and Retchitsa. The minimal critical value recommended by the method of a risk calculation is equal 4. So it is possible to conclude that risks of a degradation of river ecosystems are absent and their condition is quite well in a case of these towns. However all this does not answer a question of a risk probability at these "hot sites" in the case of negligible alterations in ecosystems. We have applied a principle of a percentile selection of the TBI critical values for a risk calculation on a 25 % basis. Such a value was 7.5 for Retchitsa and 6.5 for Mozyr. Respective values of a risk probability were obtained using calculated critical TBI values (Table 2).

**Table 2** The TBI index (*tbi*) and risk probability (*p*) values for investigated stations at different critical *tbi* values and respective values of a correction coefficient *k* (Table 3)

Localization of the sites Above – below of sewage discharge	Gomel		Retchitsa		Mozyr		Minsk	
	<i>tbi</i>	<i>p</i> (%)	<i>tbi</i>	<i>p</i> (%)	<i>tbi</i>	<i>p</i> (%)	<i>tbi</i>	<i>p</i> (%)
Above 20 km	—	—	—	—	—	—	10	0
Above 2 km	9	0	8	0	8	0	8	0
Above 0.2 km	6	0	—	—	—	—	—	—
Sewage discharge	3	80	7	96	6	82		
Below 0.2 km	3	80	7	100	6	89	3	80
Below 3 km			8	13	6	72	3	100
Below 5 km	6	20	8	1	—	—	—	—
Below 8 km	9	0	—	—	7	18	—	—
Below 9 km	8	0	—	—	—	—	—	—
Below 10 km	9	0	8	0	7	11	—	—
Below 11 km	8	0	—	—	—	—	—	—
Below 15 km	8	0	8	0	8	0	—	—
Below 23 km	9	0	—	—	—	—	—	—
Below 100 km	—	—	—	—	—	—	8	0
Critical TBI values		4		7.5		6.5		4

### 4 Conclusions

So the biotic index TBI may be used for the ecological risk assessment based on a probability approach. It is shown that a probability of ecosystem degradation depends in first on how much closely a sewage is situated. In a site of a sewage discharge and depending on its volume the risk probability runs up to 80% ~90% and in some cases it equals 100% that is a system has become degraded. In conditions of Belarus a degree of the ecosystem quality restoration is quite high. In

most cases along a 15 km distance with a stream of a river the risk probability decreases to values corresponding to those above the site of a sewage discharge. Data obtained evidence the necessity of use of a multi – level system of the ecological risk assessment. The international level is necessary for a comparison of a risk probability in different countries with different systems of use and protection of water resources. The national level is necessary for a comparison of basin and regional levels. The basin level is applicable at comparison of tributaries of different order. Regional level is best for evaluation of a concrete source of pollution on principle “with and against the stream”. For each level the corresponding minimal critical values of assessing factor may be used. So if generally accepted minimal value of the Woodiwiss index for risk calculations equals 4 then for most of rivers of Belarus the risk probability is absent even if a river flows through the settlements. In order to inter – calibrate index values for a comparative analysis between international, national, regional and basin levels a percentile principle of establishment of critical values of the Woodiwiss index equal to 25% may be applied.

A given approach has allowed to monitor more precisely a probability of alterations in ecosystems and to reveal a possibility of further degradation of a system at early stages. The use of risk probability values for river systems calculated for different places with different degree of anthropogenic impact allows to isolate reference sites. The use of them is recommended by the EU Water Frame Directive as one of general mechanisms of a comparative analysis of a water quality. A risk probability values gives a possibility of a cartographic image of a state of water ecosystems using GIS system.

Thus the definition and use of risk probability values for river systems is an universal mechanism of determination and monitoring of a water quality and may be a tool for taking decisions on a water resource management.

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# Comprehensively Promoting the Ecological Project Construction for the Yellow River Basin Soil and Water Conservation on the Basis of Science and Technology as the Forerunner

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**Abstract:** Based on summary of recently scientific research for soil and water conservation in the upper and middle reaches of the Yellow River, especially the great research projects such as fundamental research, applied technology and scientific & technological demonstration and popularization, aiming at the existing problems at present. The objective and plan of scientific and technological work for soil and water conservation are put forward.

**Key words:** soil and water conservation, scientific research, problems, objective and plan

## 1 Review of scientific research progress in recent years

### 1.1 Fixing attention on tackling key problems, and providing technological support for management of the sand – laden and coarse sediment areas of the Yellow River

The key for solving the problems of the Yellow River sediment is to strengthen management of Coarse Sand Producing Region in the Middle reaches of the Yellow River, especially the coarse sediment concentrated region, and building “The First Defence Line” for Yellow River coarse sediment control. In 2004, Based on the idea of the Party Committee organization of YRCC, that is to make further investment and strengthen control on the coarse sediment concentrated region of the middle reaches of the Yellow River, Upper and Middle Yellow River Bureau (UMYRB) of the YRCC actively participated the research of “Definition on Source Area of Centralized Coarse Sediment in the Middle reaches of the Yellow River”, and accomplished the research about their characteristics of nine key branches. In 2005, UMYRB began another study about “How to harness the Centralized Coarse Sediment area in the Middle Reaches of the Yellow River”. Through analysis of large amount of data and field investigation, and regional soil erosion environmental characters (environmental, economic & social characteristics, dynamic characters and comprehensive factors) and adaptability of controlling measures (dam system, debris – retaining reservoirs, sloping soil loss control measures and comprehensive harnessing), a division of the control areas was finished in a scientific way (loess soil harnessing area, soft rock area, wind erosion area), key points for control in each area was confirmed, and put forward to scientifically harnessing idea, objective, key control measures, layout structure, collocation mode and countermeasures. In 2006, the study about “Key Technologies for Sustainable Control Sediment in Coarse Sand Producing area in the Middle reaches of the Yellow River” was implemented in to seek out key technologies necessary in controlling the coarse sand producing area in the middle reaches of the Yellow River, meanwhile taking into account the need of implementation of the Yellow River ecological project. The research would pay great attention on the objective of sustainable interception or reducing sediment by small watershed dam system construction, as well as several other aspects; rational control of the area and volume of dam system project; analysis of dam system anti – flood risk; stair – stepping and composite relations and numbers collocation ratios of backbone dams and small and medium – scale soil – retaining dams, and etc.

## **1.2 Based on the construction of the demonstration harnessing zones and World Bank financed – project, actively implemented operative and new technologies research and popularization**

In recent years, UMYRB has constructed high standard and high – tech typical soil control demonstration zones in the first and the third sub – regions of loess hilly and gully area, including Jiuyuangou, Jihe and Qijiachuan watersheds to construct advanced – technology soil and water conservation demonstration area, meanwhile, develop applied as well as operative technologies. The “Technology for soil and water conservation” and “Water saving irrigation technology” developed in Jiuyuangou demonstration zone by Suide Soil and Water Conservation Station has helped popularize the new species of red date which area is 198.8 hm<sup>2</sup>, water saving and rain gathering area 26,139.6 m<sup>2</sup>, water storage volume 2,458.2 m<sup>3</sup> and irrigated area 92 hm<sup>2</sup>.

In the process of the World Bank financed – project for Loess Plateau soil and water conservation, according to the requirements in the evaluation report by World Bank, and the actual situation of each locality, the study on monitoring method and evaluation system for terrace construction, vegetation and small watershed projects has been carried out to solve key problems and technologies. By “3S” technology and combination with regular supervising method and mathematical statistics, draw correlation factors can be extracted that have influence on terrace quality, vegetation coverage, density of crop and thematic information of small watershed dam system. UMYRB has brought forward terrace supervision & evaluation system, vegetation project evaluation system and small watershed supervision & evaluation system respectively. On the basis of treatment and analysis of spatial information & data including satellite images, UMYRB has set up the transformational relations between satellite images of mid & high accuracy and the actual objects by means of mathematical analysis and calculation. What we’ve done has solved those problems that are difficult by regular supervising methods for their low accuracy, long cycle and low – resolution information sources. Now we could make accurate spatial analysis and supervision with fast speed, and is capable of providing service and technological support in aspects of ecological environmental evaluation, measures layout, benefit analysis, evaluation and anticipation for not only the World Bank financed – project, but even the whole soil and water conservation project in the Loess Plateau.

## **1.3 On the basis of science and technology, and effectively promoting the transformation from conventional state to modern mode in soil and water conservation**

For the national “948” projects “Introduction of Exotic Superior Leguminosae & Grass for Soil and Water Conservation” and “General Survey and Monitoring by Remote Sensing for Soil and Water Conservation of the Yellow River Basin” undertaken, UMYRB has attached much importance on introduction of overseas advanced technologies, and effectively promoted the transformation from conventional state to modern mode in soil and water conservation, which has played an important role in the soil and water conservation ecological construction. 15 exotic species for soil & water conservation plant in adaptation to different areas in the Loess Plateau have broken through the nonexistent situation of plant genetic resources in the area, and the selected fine forage grass, perennial *Lathyrus Latifolius*, *Bromus biebersteinii*, *Bothrichloa Ischaemum* and *Poa canbyi* have also passed the regional test and have become popular in Qijiachuan demonstration zone of the Yellow River soil & water conservation ecological project, as well as in provinces of Shaanxi, Shanxi, Qinghai, and etc., the planted area of which is up to 449.5 hm<sup>2</sup>. Therefore, remarkable ecological and economic benefits could be gained. The imported and internationally advanced “3S” technology and apparatus has become the best of all “3S” application systems in field of soil and water conservation in China. A dynamic monitoring system platform has been successfully established for ecological environment supervision of severe soil loss region in the Loess Plateau, and geographic information system, 3D visual information system, and three – dimensional browsing

system for soil & water conservation of 1st level branch of Yellow River has been developed. UMYRB has established the background database for dynamic monitoring of ecological environment of Yellow River Basin soil & water conservation for the first time, which is a large – scale application system by use of “3S” technology in soil and water conservation ecological environmental construction, and series results have been obtained so far.

#### **1.4 Finishing the layout of soil & water monitoring stations and networks, and speeding up soil and water conservation information system construction as a foundation for “Three Yellow Rivers” project**

At present, 13 small watershed dam system monitoring stations (spots) for soil and water conservation have been set up in Datong County of Qinghai, Dingxi and Huanxian Counties of Gansu, Xiji County of Ningxia, Qingshuihe County, Jungar Banner of Inner Mongolia, Yonghe and Hequ Counties of Shanxi, Pagoda District of Yan’ an City, Mizhi County, Hengshan County of Shaanxi, and Jiyuan City of Henan. And 8 typical small watersheds in the first and the third sub – regions of loess hilly – gully area and hilly – gully region of tableland have been selected to monitor soil loss. Now 17 runoff monitoring stations, 92 rainfall stations, 3 meteorological stations, 59 runoff plots, 1 runoff plot monitoring station have been built up. One set of fixed artificial rain simulator and its auto – control system has been respectively installed in the relay station and the key station of telemetry equipment accordingly, and research on relevant technical problems has been developed in Qiugou test area of Nanxiaohegou watershed of Xifeng City, Gansu Province. Meanwhile, construction for network infrastructure and electronic government has been developed, including construction of network infrastructure, office automation system, and Yellow River soil and water conservation database. UMYRB has also put forward five application systems, including database management system, 3D analysis system, soil – retaining dam management system, three – dimensional visual simulation planning system for small watershed dam system, and etc. , to provide service for professional works as soil and water conservation control, planning, and monitoring, which has laid foundation for construction of “Digital Soil and Water Conservation”.

#### **1.5 Actively innovations in pilot study and technical means, and providing service for the soil and water conservation ecological construction**

On the occasion of warping dams as the national “Highlight” hydraulic engineering, and combined with the technical superiority that we have already gained in test and research on soil – retaining dam construction, UMYRB has developed some key technological research topics, for example, “Study on small watershed dam system planning and digital analog simulation technology”, “Investigation on status quo of soil loss in soft rock area and control measures”, “Research on evaluation method of gully and dam safety in coarse sediment area of Yellow River”, “Investigation on small watershed dam system monitoring method and evaluation method”, and etc.

In the meantime, UMYRB has introduced “3S” technology and systems engineering theory for investigation and planning of small watershed. And based on research made of dam system monitoring measures and evaluation system by application of “3S” technology, UMYRB has established small watershed dam system information management system and Digital Elevation Model (DEM), and imported the most advanced series of monitoring equipment in water conservancy industry, including high – resolution photogrammetry scanner, digital photogrammetric working station, graph working station, and GPS.

Furthermore, according to the demand of soil and water conservation ecological construction project, UMYRB has successively added items for monitoring social, economic, ecological benefits and benefits in runoff and sediment reductions, as well as built up microclimate automatic monitoring station locating at the Tianshui, Xifeng and Suide, realizing automatic collection, storage, feedback and processing of monitoring data.

## **2 Main problems existing in soil & water conservation**

### **2.1 Fundamental research is lagging behind production practice**

At present, the fundamental research of soil loss in the Loess Plateau is quite inadequate and no big breakthrough in the field of soil loss regularity, soil erosion mechanism and dam system relative balance theory has been acquired. What is more, innovations about benefits evaluation method for soil and water conservation, and in technique and method for design of soil and water control measures are very necessary, but do not success. Monitoring of soil loss began in the 40s of twenty century, and a large amount of monitoring nets, stations and spots have been built since then, by which monitoring data can be obtained; but monitoring on soil loss has not drawn high attention, mainly manifested in small amount of investment, equipment lack, no unified organization and planning. Thus, in the different stage, investigators in different places, of different disciplines may set up monitoring device according to their different purposes, and resulting in disagreement in monitoring standard, measures and contents. And monitoring data obtained are of incomparability. Besides these, spatial arrangement for soil loss monitoring is inconsequent and non – representative, and there are no monitoring point in some regions, which could not reflect provincial characteristics and regularities. At present the main research method of soil loss is through hydrologic sediment monitoring of field runoff plots and small watershed monitoring station. But these monitoring devices have low automaticity and fail to completely collect process information, which influences the process study. Other factors include the irrational design of monitoring device (like that of diversion box), inaccurate runoff observation and sediment load sampling. Though remote sensing (RS) technology has brought hope for big area monitoring of soil erosion, yet the technology could only be used to make indirect evaluation on soil loss through interpretation of influencing factors, but soil erosion intensity can not be obtained directly.

### **2.2 Being deficient in science and technology investment, and lacking fixed investment input system**

Soil and water conservation is involved in wide fields, there are a great many scientific problems about soil and water conservation that need to be solved. But investment by government at different levels is much deficient compared with that of demand. Before 2000, science and technology investment for soil and water conservation consisted of irrigation operating expenses, special investment and foreign capital importation. During the period of the Tenth Five – Year Plan, along with the government transitional investment orientation and continuous increase of wages, allowance and commodity price, the irrigation operating expenses as science and technology investment for soil and water conservation has been replaced by temporary arrangements from capital construction investment. Due to its limited amount, this proportion of investment could just be used to solve some technological problems that we may come across in the implementation process of the project or for some short – term projects. The fund of fundamental research, strategic study and forward looking of major problems are quite deficient.

### **2.3 Shortage of professional science and technology staff, and imperfect in scientific research system and mechanism**

Generally speaking, the total number of staff engaged in scientific research is not enough, and staff structure and distribution is also improper. High level professional technicians and research teams are shortage. In addition, the scientific research cycle for soil and water conservation is fairly long and slow in taking effect, and years of deficient investment has caused relevant scientific research topics discouraging. Experts in charge of a research topic is not clear about his or her duty and right, and has no power to decide the team members and expenditure. The relation of income distribution is not harmonious; Input and output is not proportional; the staff enthusiasm of



participating in scientific and technological work is not high due to the influence or driven by different functions and interests. Staff teams engaged in soil and water conservation research are not stable, especially in grassroots research institutes and testing stations. Due to their relatively low salary, these scientific personnel sometimes has no choice but to take up works concerned nothing with soil and water conservation in a certain period of time for their livelihood, resulting in severe talent loss.

## **2.4 Lagging in production popularization, and low efficiency in production transformation and scientific contribution**

The function of soil and water conservation project is to improve ecological environment and reduce sediment flowing into the Yellow River. The project has good social benefit and many people can benefit from these projects. Since the benefits of different interest groups are difficult to separate, the technological production are difficult to go into market. Production transformations are mainly promoted by the financial support from either the central or the local government. Due to the imperfect construction of science promotion institution, the result is that there is no any long, medium and short term programs and detail objectives having been formulated, and lack of policy, mechanism and funds for scientific and technological production transformation, which make it lag behind in popularization of technological productions and inefficient in scientific contribution.

## **3 Objective and plan for scientific research in soil and water conservation on the stage**

### **3.1 Objective**

Making innovations and development, sticking to “People – concentrated” scientific view of development, taking an active attitude in promoting scientific and technological innovations for soil and water conservation, extending academic exchanges and bringing forth new ideas in management mode, strengthening pilot study of key technologies for soil and water conservation, emphasizing on importation and application of new technologies, deepening reform of scientific research system, upgrading the whole scientific and technological power, promoting breakthroughs in great scientific problems, providing technological support for the Yellow River soil and water conservation ecological project construction.

### **3.2 Plan for scientific and technological work**

#### **3.2.1 Making further research on regularity of the Loess Plateau soil loss, and developing mathematic model for soil loss in the Loess Plateau**

Since the regularity of soil loss in the Loess Plateau is quite complex, and restricted by the development level of means and method for test observation available, as well as its set contents, no breakthroughs in research fields such as soil loss regularity, basic laws of erosion and sediment yield, and dam system relative equilibrium theory have been procured at the moment, bringing on restrictions for further development of soil loss control in the Loess Plateau. How to guarantee the stability and safety of soil and water conservation project? How to direct planning and design of soil and water conservation measures in a more scientific way? How to give a more accurate forecast for flow and sediment production state in the Yellow River Basin? All these are the key problems that in urgent need to be solved. Aiming at the practical situations that there lacks scientific, systematic, and reliable fundamental information data in project plan and design for soil and water conservation, and lacks advanced and applied evaluation system and means in design and benefit analysis evaluation for soil and water conservation, topics that in urgent need for development are further research of soil loss regularity, and study and development for mathematical model of soil loss in the Loess Plateau, while considering the actuality of soil and water conservation need in local area.

### **3.2.2 Actively innovations on the basis of “Physical Loess Plateau”**

The physical features and erosive environment in the Loess Plateau are interactive results by many factors, origins and erosion types, which make it very difficult for us to scientifically apprehend and master the soil loss regularity. And much regularity has not been discovered and seized on the whole in the process of development and control. Therefore, the ultimate objective, that is, the sediment flowing into the Yellow River is reduced and ecological environment be in a positive cycle, could be realized only when series of key theoretic problems be solved and used to direct the practice of the masses. At present, construction for “Physical Loess Plateau” has been sure as the important schedule for the general framework of keeping a healthy life of the Yellow River. With the good opportunity, we should focus on breakthrough of key theoretical problems and techniques for soil and water conservation, further investigation on soil loss regularity and continual increase in scientific innovation capability for soil and water conservation. We should try every possible way to make achievements in study of small watershed dam system relative equilibrium theory and indicator system, in research on division of ecotype zone and environmental evolution in the Loess Plateau, in investigation on benefits evaluation of water and sediment reduction for soil and water conservation, and in research on environmental capacity, ecological construction target and way of target – shooting in different zones. Through all these efforts, we hope to acquire research findings with applied value as soon as possible, and provide technological support for decision – making in management of soil and water conservation.

### **3.2.3 Strengthening the construction of ecological environment monitoring system for soil and water conservation, and providing technical support for “Digital soil and water conservation” construction**

According to the need for soil and water conservation ecological environment construction and overall requirements for “Digital soil and water conservation” construction, we will continue to implement prototype observation of typical small watersheds in the first and the third sub – regions of loess hilly and gully area, as well as those in hilly – gully region of tableland. We will set up standardized small watershed observation system with all – sided contents, scientific and normative means of observation, thus providing scientific support for research on soil loss regularity and set up of the prediction system for soil erosion and sediment yield. Main contents include; renewal and reconstruct of test and observation stations (nets), infrastructure, instrument and equipment for soil loss; readjusting and perfecting of items to be observed; building up relatively advanced automatic forecasting system; improving data processing technique; setting up underlying data base of prototype observation; developing research on soil loss predicting model and key technology in monitoring of soil and water conservation ecological environment. We plan to upbuild a fast and convenient system for data collecting, processing, publishing and sharing, for the purpose of overall and in situ monitoring and control of soil loss and status of soil and water conservation, and scientific evaluation of management effect, thus providing timely and reliable data support and scientific foundation for government on different levels to formulate policies, programs and decision – making.

### **3.2.4 Further improving the people understand of science and technology providing support to soil and water conservation, and setting up an intelligent, capable and high effective soil and water conservation teams**

Soil and water conservation is the main body of ecological environmental construction, and change from traditional way to modern mode must increase its technology ability. It is necessary to consolidate and increase soil and water conservation benefits, to realize sustainable development and the overall objective of our country in ecological environment construction. We should make further reform and mechanism transformation with reference to actual situation, establish a system adapted to socialist market economy and a scientific management system for modern soil and water conservation by following the self – development law of science and technology, and take an active attitude to identify ourselves with the frontal zone for soil and water conservation ecological

environment construction. UMYRB will carry out the policy of “Stabilizing on end” and strengthen our intelligent, capable and high effective brainpower with optimized structure and rational distribution, to improve our innovative capability in science and technology, to ensure and accelerate its development, and achieve much better results in ecological, economic and social benefits.

### **3.2.5 On the basis of the market law, and improving the scientific service of soil and water conservation**

We should introduce, attract and popularize a batch of advanced and applied technological production, either domestic or overseas, to build up high – tech, high – benefit sci – technology demonstration bases for soil and water conservation, which could speed up technological productions transformation in one aspect, but may provide powerful technical support for big demonstration zone construction in the Loess Plateau and sustainable development in comprehensive benefits for soil and water conservation. The emphasis should be put on development of information system for soil and water conservation management, inquiry system for scientific and technological achievements, and software system for programming and design, as well as demonstration and popularization of superior species and high – technology computer technology.

# Strengthening Reservoir Operating System Maintaining the Healthy Life of the Yellow River

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**Abstract:** The paper investigates the important role of the optimization operation of reservoir for maintaining the healthy life of the Yellow River and puts forward to appropriate measures in strengthening reservoir scientific operation for maintaining the healthy life of the Yellow River.

**Key words:** reservoir, operation, the healthy life of the Yellow River, role

The basin of the Yellow River is insufficient in water resources with unevenly distribution in space and time. At present, The river is facing various water problems such as the unsteady volume of water, muddy and dirty water and the major problem lies in less water and more sand, water and sand from different origins. Consequently, the gap between water supply and demand has become more severe and economic development and the living standard of people have been blocked and restricted. As far as the river itself is concerned, its innate nature is under the threat. The key to solve such problems involves increasing investment and reducing expenditure, adjusting the proportion between water and sand. Furthermore, it is necessary to build a water – saving, anti – pollution and environment – friendly society and reasonably deploy and optimize water using with high efficiency so as to improve the ecological environment. The operation of reservoir takes priority over all the measures for it effectively deals with main problems. It also imposes important influence on the management of water resources and wholly arrangement of water for production, life and environment. In addition, it can guarantee “no embankment breaching, no river course running dry, no pollution over standard, no riverbed rising”. Therefore, adhering to the scientific concept of development and following the law of natural economy, we should further improve the system of the regulation system of water and sand and strengthen the intergrated operation and management of reservoirs. Furthermore, we carry out the principle of unified, lawful scientific and profitable operating reservoir so that the load ability of water environment can be enhanced, the basic function of river way be recovered constantly and the healthy life of river be maintain. Concequently, the economy of the society will endlessly gain drive to develop and the harmony between human being and the nature will obtain.

## 1 The important role of opermizing reservoir operation system for maintaining the healthy life of the Yellow River

On the mainstream of the Yellow River, many reservoirs have been set up such as Longyangxia, Liujiaxia, Wanjiashai, Sanmenxia and Xiaolangdi. In recent years, we practise methods of operation in regulation of water and sediment, distribution of water, regulation of flood control and ice – jam flood control through rational operation of a reservoir or a group of reservoirs. All the practices positively have influenced on optimizing and distributing water resources, preserving the ecological environment, maintaing healthy life of river. Therefore, the economic development has made great achievement and the social, economic and ecological benefit have obtained dramatically.

### 1.1 Sediment – water regulation of the Yellow River can constantly enhance the discharging ability and gradually recover the basic functions of the river

Since the 1990s, excessive exploration of the Yellow River by people in the area along the

river, along with the dry weather, less incoming water, has caused that large amount of water for transporting sand are misappropriated, the water flowing into the lower Yellow River lessened dramatically and the gap between water supply and demand is more and more severe. In addition, the silting of the downstream of river way has been aggravated and the discharging ability has greatly been reduced. Therefore, those put increasing strain on flood control. Bankfull discharge reduced to about  $2,000 \text{ m}^3/\text{s}$  from  $6,000 \text{ m}^3/\text{s}$ . In 2003, the flow of the flood is  $2,400 \text{ m}^3/\text{s}$  in Lankao section of the Yellow River in Henan Province which caused severe disaster. As a result, near 120,000 people in the floodplain suffered from the demoniac flooding. To resist the flood, since 2002 on, the Yellow River Conservancy Commission carried out the regulation of water and sediment successively for five times and employed the "artificial flood peak" to scour the downstream course of the river. Thanks to those practices, the sedimentation on the downstream has gotten improved, the discharging ability has increased and the downstream course has been eroded. The minimum discharging ability increased to  $3,500 \text{ m}^3/\text{s}$  from  $1,800 \text{ m}^3/\text{s}$ . The basic function of the river is recovered gradually.

## **1.2 Sediment – water regulation of the Yellow River makes the ecological system of the river better and effectively keeps the riverbed from rising because of sediment silting**

Because of less water and more sand, water and sand from different origins, the river constantly is silting and rising and the main river channel becomes narrower. Consequently, the downstream of the river has been the secondary suspended river and even the ecological system of wetlands along the river deteriorated ceaselessly. To change this situation, the Yellow River Conservancy Commission regulated water and sand for four times and scoured 30 million tons of sands into the sea. Therefore, the main channel of the downstream was eroded comprehensively and riverbed descended by 1m. The fifth regulation of water and sediment discharged 6.010 million tons of sands and effectively improve the form of the river. Moreover, the sedimentation is reduced and the silting and raising of the riverbed on the downstream is checked.

Since 2002, the five regulations of water and sediment also provide beneficial condition of water volume for the recovery of the wetland ecological environment. This year the fifth regulation will infuse over 20 million  $\text{m}^3$  river water into the wetland on the river mouth so big or small pits and ponds spread all over the area of inlet and reservoirs dotted with the river ripple. As a result, a large area of water surface and wetlands form so that it can reduce the phenomenon of lessening wetland caused by the intruding of seawater. The wetland area is increasing with the speed of 3,300 hectares per year and reached to 20,000 hectares. Also, the area of tamarisk becomes 130,000 acres and the species wild plants in the reserve are up to 393. The species of birds of the delta has added up to 283. The biodiversity resources is richer and ecology is developing in the direction of multiplicity and stability.

## **1.3 Sediment – water regulation of the Yellow River is beneficial to the adjusting and straightening out river regime and can shape or maintain river course during middle water level**

The Yellow River is an accumulating and wandering river with severe silting, shrinking form and wide and shallow river course. Besides, it flows disorderly with unstable channel and undeterminedly swinging of the mainstream. Furthermore, there are lots of sand bars and bifurcations. Some diagonal, traverse and rolling streams often occur. Especially during low flow, the streams meander with the meandering of the river bend and often form abnormal river regime. As a consequence, the low flow can bring about big dangers or disasters. The river regime follows the rules that low flows follow the river bends and floods tend to go in straight line. Complying with this rules, we carry out united operation of multi – reservoirs, regulate water and sediments and create artificial medium floods. Through exerting the bed – forming role of the flood, channels can be dredged and smoothed, relatively stable normal channel can be shaped and the ability to discharge

flood and transport sediment may be improved. In March of this year, the Yellow River Conservancy Commission launched the test of using snow flood to scour the bed elevation in Tongguan in order to straighten out the river regime of Tongguan Reach of the Yellow River and to form single and smooth main channel.

#### **1.4 Sediment – water regulation of the Yellow River brings benefits to the reservoir and lessen the negative effects caused by the construction of reservoir**

Reservoir sedimentation regime can be adjusted through regulating water and sediments and discharging large number of sands out of the reservoir. In addition, the practice is able to reduce the sedimentation of the reservoir, increase benefit of reservoir and boost the healthy environment of the reservoir. Therefore, the life of reservoir is lengthened. In 2006, the fifth united regulation is operated through Sanmenxia and Xiaolangdi. density current was created successfully in Xiaolangdi again and 8.41million tons of sands were discharged out of the reservoir.

Since the operation of Wanjiashai reservoir in 1998, water storing in the reservoir reduced the peak and discharge of flood in the Tongguan during peach flood period, hence, there is almost no scouring or a little bit silting of the riverbed, which is different to the scouring and descending of the riverbed before the operation of the reservoir. With the purpose of reducing the influence of Wanjiashai on the bed elevation Tongguan, the Yellow River Conservancy Commission took the test of using the discharge during the peach flood to scour the bed elevation in Tongguan from 23 to 29 in this March. Through the operation of Wanjiashai reservoir, the process of peach flood is optimized, the form of silting in Wanjiashai and Sanmenxia is improved. Consequently, the total erosion of the Yellow River little north stem section reached 7.1million tons and the riverbed elevation in Tongguan lessened by 0.2 m.

#### **1.5 Regulation of water and sediments can effectively bring the social and economic functions of the reservoir into play**

Regulation of water and sediments can not only enhance the natural function of the river but also exert its social and economic function. It also helps to optimize and manage water resources, comprehensively manage water for daily life, industry and ecology and relieve the contradiction between water supply and demand. Furthermore, the comprehensive results of power generation, irrigation, landscape eco – tourism and water supply can be obtained. Finally, it enhances the sustainable development of economic and social environment in river basin and realizes the harmonious relationship between human beings and nature. Since 2002, the Yellow River Conservancy Commission operated together many reservoirs such as Wanjiashai, Shanmenxia and Xiaolangdi to regulate the water and sands. Under the precondition of assuring the safety flood control, the regulation ensured the water supply for people and industrial and agricultural production along the Yellow River. In extreme autumn flood of 2003, through “the united operation of four reservoirs”, many flood peaks were cut down, the loss by disasters was reduced and good social and economic benefits have achieved so as to limit the flood in Huayuankou to the range of 2,400 ~ 2,700 m<sup>3</sup>/s, and the rate of reducing peak reached to 40% ~ 50% and reduced the loss by flood efficiently with the realization of multi – goals such as flood – hindering, disaster – mitigating, sedimentation – reducing and flood resourcing.

#### **1.6 The reasonable operation of the reservoirs can effectively deal with the dried – up of the Yellow River crisis and ensure the river not dry up**

Since 1970s, because of adverse condition of incoming water and sediment and excessively exploitation of water resources, the downstream of the river dried up frequently. Since 1972, the Yellow River dried up for 21 times. Especially in 1997, the total drying – up days of are up to 226 days and the length of dried – up section is 704 km. Since the Yellow River Conservancy

Commission is entitled to implement integrated operation and regulation of the water resources in 1998, the many dried – up crises were removed through many measures like rational use and operation of the reservoir. At present, the river has not dried up for the successive seven years. For instance, when Tongguan section in middle stream had the discharge of  $0.95 \text{ m}^3/\text{s}$  on 22 July 2002, Wanjiashai timely discharged water during the critical period. As a result, the river did not dry up.

### **1.7 Utilization of the reservoir scientific regulates and controls the water flow and fully makes use of rainfall and flood resources and reduces the losses caused by flood and drought**

Due to the unevenly space – time distribution of rainfall, flood often alternates with drought in the basin of the Yellow River. We store floodwater and combat drought, timely store and keep water and reduce flood peak through operating the reservoir. Meanwhile, reservoirs are helpful to make full use of resource of rain and flood, strive for actively flood control and drought resisting and reduces the losses by flood and drought. Fighting the flood of Weihe in 2005, Office of Flood Control and Drought – Relief in Shaanxi Province utilized fully three reservoirs—Heihe, Shi – tou – he and Fengjiashan to enhance flood rearrangement. In the first flood process of Weihe, the flood peak of the mainstream was cut down. Besides, Sanmenxia is used to discharge the flood during the flood period, so the pressure of withstanding the flood was eased and flood is smoothly discharged. Hence, less loss is caused by the flood.

### **1.8 Utilization of the reservoir adjusts the water volume and effectively guards against the pollution of water environment in the river**

Combining self – purification function of water with reasonable regulation of the reservoir, we can dilute contaminated water body and increase water environment load to improve the water quality and mitigate water environmental pollution of river. In the afternoon of January 5 2006, the accident of diesel fuel leak happened in Gongyi City of Henan Province, which bring about oil pollution of downstream of mainstream Luohe. At the same time, it also threatened to the water quality of mainstream of the Yellow River. Responding to the emergency, the Yellow River Conservancy Commission timely enlarged discharge volume of Xiaolangdi and shut the gates of Guxian and Lulun reservoirs. In addition, more measurements were performed on the important river cross section monitoring on the supplying water source in the downstream to solve water pollution of the river.

## **2 The measures for reservoir operating system and maintaining the heathy life of the yellow river**

### **2.1 Strengthening the unified operation and management of reservoirs**

At present, most of the reservoirs built on the mainstream of the Yellow River are under the management of different units and departments. For example, 18 reservoirs on the upper stream of the river (12 reservoirs have constructed and 6 reservoirs are under the construction) respectively are administrated by nine units. The pattern of department division, section division is still not changed. If the reservoirs continue to adopt the original mode of operation and management and only perform their own tasks, the comprehensive efficiency of using basin cascade reservoirs will be affected and a series of ecological and environmental problems will emerge. Furthermore, with West Area Development and electrical system reform in recent years, the fever of hydroelectric power exploitation on the upper stream started. The involved sides slice up the market and compete with each other for the right of hydropower development. Even some projects have started the construction before obtaining complete approval procedure so that the hydroelectric development is blind and disorder and lack management and planning. Therefore, it is an irresistible and imminent trend to implement the general operation of reservoirs and the unified management of hydropower

development. We should strengthen integrated management and control of basin water resources. We also explore and establish the mode of watershed management combining the government's macro - adjustment ability, basin democratic consultation, quasi - market operation with the participation of water user so as to strictly strengthen the development and management to safeguard the sound ecological environment. In addition, we should set up efficient and authoritative institute that is responsible for the centralized control of hydropower development and crystalize responsibility for coherent units. Increasing consultation and communication, we establish system of coordinating the upper and lower river with the group of reservoirs and mechanism of cooperating relevant departments of flood fighting, power generation, irrigation, water supply, shipping, fishery and tourism. Meanwhile, it is necessary to strengthen supervision and inspection, unity and cooperation and close cooperation. Moreover, it is also essential to enhance the unified operation and management and to rigorously plan and manage hydropower development in order to keep good order of hydropower development and fully make use of reservoirs to do such work as water and sand regulation, anti - pollution and draught - prevention etc, well and further preserve the ecological environment, keep the health of the river and explicitly define ecological compensatory body.

## **2.2 Strengthening reservoir scientific regulation and improving the level of modernization of operation**

The integrated operation of reservoirs is enormous system engineering and involves numerous complex technical problems so it is not adequate to use traditional means of operating for the demands for timeliness and modernization of resources regulation. We should speed up the construction of digital water resources regulation project, establish and perfect modern system of managing that is concerned with automatic system of information collection, computer network system, the management system for the water amount regulation, and the supervision center for yellow river resource as well as decision support Systems. In addition, the system also includes information platform of reservoir scheduling, hydrological information platform built on the upper and middle reaches, video system for consultation. Most important, it involves control center, hydrological station monitoring network system, all - digital water quality auto monitoring station and LD Automated monitoring system diversion port. At the same time, we should exchange and share the information of reservoirs and build system of water resources management for maintaining the healthy river. Next, we should make researches on the mode of water - sand joint operation of yellow river reservoir and multi - reservoir ecological management on watershed scales and further perfect the index system of scientific operation of reservoirs. As the result of the evaluation of the environment of river and measures of management and control, we can scientific recognize and evaluate the health index of a river. Furthermore, we should come up with the evaluating method and index system to weight the relationship between social and economic benefits and ecological benefits. On the base of completely understanding the ecological problems facing a river, grasping the natural rule of change and water demands and ecological water demands of creatures, ecological water demands of a river, ecological base flow and critical flow of the river without eroding and silting can be calculated. Then we study how the regulation of water and sediments gets optimal dredging efficiency of downstream in the shortest possible emptying time through minimal water quantity in order to establish theoretical technological system of regulating water and response system of ecology and environment. After investigating compensation mechanism and the changes of interests of related object before and after the ecological operation, the relationship between the movement of water and sands and the change of sediments can be further explored and establish the balanced relationship between water and sands. Hence, a scientific and feasible plan of comprehensive operation of reservoirs can obtained and a theme of implementing water regulation further can be perfected. Besides, we should make different protocols with combination of different ways of operating, discharge conditions with sediment concentration. Moreover, we should build a quick - responding and powerful operating team with perfect skills and good proletarian. We can count on many technologies such as weather radar, global positioning system, satellite remote



sensing technology, geographical information system, telemonitoring and real – time image and data network transmission to strengthen the monitoring of water volume and quality and forecast of weather and water and rain regime and explore the prediction of sand and water level. Therefore, the early – warning system can be improved. At last, we carry out remote auto monitoring, control, supervision and early warning to reservoirs, major hydrometric station, water quality monitoring station, the mouth of ushering water and control node, which provide many kinds of information service for the policy and scientific analysis of water regulation. Hence, the level of management of operating reservoirs and operating results can be improved.

### **2.3 Improving the regulations and policy for management of reservoirs operation and strengthen management and operation by law**

Valid regulations and policy with the strict execution are the guarantee to operate reservoirs and manage water resources. As a result, it is indispensable to intensify the economic and legal means to establish the system of management and water resources regulation and build ecological compensation mechanism and water volume adjustment compensation mechanism. We need to adhere to the principle “he who is benefited shall compensate” and make explicitly the main body of ecological compensation. Through improving constantly water related regulation and policy and enforcement system, we can constitute water related management system and new system of regulating water resources according to the modern development. In addition, it is necessary to further revise and improve existing statute, regulation and policy related to reservoirs operation and integrated management of water resources. The linking and coordination between laws and regulations need strengthening and operateability needs improving. In addition, we should implement the Yellow River water resources regulation, enhance the macro – control and management of water resources and administration of reservoirs operation legally and regulate water related activities of humans. Also, it is essential to act on the principle that the existing law is strictly observed, the law is strictly enforced and violations of the law must be punished so that the order of managing water resources could be maintained. Consequently, many aspects of hydropower development engineering can be started following some regulations, such as, project determination, investment, construction, water quantity allocation, management system of beneficial operation of project and benefits after construction. Meanwhile, the integrated management system of water resources should be established, which involves the combination of exploration with preserve, of water volume with water quality, of urban with rural, of the surface water with ground water, of drawing water and using water and of supplying water and discharging water. Furthermore, the coordination system between upper or lower stream with basin cascade reservoirs should be established. It is necessary to build the system coordinating interests of relevant departments such as flood control, power generation, irrigation, water supply, shipping, fishery, tourism thus the work of the water management and operation can develop in the direction of standardization, regulation, the legal institutionalization, modernization. As a result, water resources can achieve sustainable utilization and positive cycle of ecological environment and the economic of the society can get sustainable development.

### **2.4 Improving the engineering system for sediment – water regulation**

The major problems lie in less water and more sand, water and sand from different origins, so regulation of water and sediments through reservoirs is the effective measure to improve water and sand conditions, flood control and sediment reduction. During this process we should adhere to “the scientific developing conception” with the human as the foundation and the harmonious development between man and water. It is essential to generally manage water sand resources of the mainstream and branches on the basin of the Yellow River and boost the system construction of control and regulation of water and sediment. In addition, we could comprehensively plan the system of control and regulation of water and sediment and as soon as possible build and accomplish the system of

control and regulation water and sediment of mainstream and branches of the river. The system focuses on major key projects of water conservancy such as Longyangxia, Liujiaxia, Haishanxia, Daliushu, Qikou, Guxian, Sanmenxia and Xiaolangdi and employs united and unified operation of all reservoirs along the Yellow River. As a result, sands of flood are efficiently adjusted, the basic flow of river is ensured during drought and the flood flow timely is lessened. Besides, the goal of trans – area and trans – time regulation is reached and the harmonious and balanced relationship of water and sands is established thus minimum of base flow for transporting sand and persevering ecology is kept for a long time. Finally, the condition of water and sands is improved, the targets such as flood water resourcing, flood control, sedimentation reduction and disaster mitigation are obtained so as to improve the ecological system of river, to increase the discharging ability of river and to avoid the river’s drying up.

### **2.5 Further optimizing the operation pattern of reservoirs to ensure the ecological flow to maintain the basic ecological foundation of the river in the downstream of reservoir**

With the increasing exploitation of water resources, the contradiction between water supply and demands has become more severe and the role of optimizing and operating water resources is strengthened. Moreover, the position of reservoirs in controlling and regulating basin water resources is heightened. In the process of flood control and building water conservancy, the original operation pattern of reservoirs neglected its possible influence on the ecology of the downstream and water environment in reservoir area so the affection by the environment and ecology appear in every way. Therefore, with the view to a general survey of the whole basin, sustainable development of the river and the maintenance of the healthy life of river, we should change the concept completely and integrate operation of reservoirs into unified regulation of the whole basin. Furthermore, we make operation of reservoirs an important means of general management of water resources in basin and establish operation pattern of comprehensively utilizing reservoirs which unifies building of water conservancy, mitigating of disaster and preserving ecology. In addition, it is necessary to improve the reservoir operation scheme, takes the overall interests and balance the relationship between the economy of the society and ecological environment. At the same time, sophisticated technology and means are employed to ensure the ecological base flow performing basic functions of the river in the downstream of reservoirs. It can also guarantee the necessary water volume to erode and transport sediments, of keeping the self – purification ability, of resisting dried – up and channel shrinkage and of ensuring aquatic organisms’ multiplication and existence. We comprehensively consider necessary volume of preserving lakes and wetlands, of keeping ecology on the river mouth and of preventing saltwater intrusion. In addition, on the basis of meeting demands preservation of the ecology in the down stream and the water environment in reservoir area, we should make full use of the various functions of reservoirs of flood control, power generating, irrigation, water supply, shipping and tourism. Moreover, we could control on the bearable scope the negative influence by reservoirs on the environment below dams and the water environment in reservoir area to restore further the ecological and environmental system, increase social, economic and environmental benefits and maintain the healthy life river.

### **3 Conclusions**

Optimal operation of reservoirs is crucial important to maintain the healthy life of the Yellow River. It can reasonably distribute and use water resources, and coordinate the relationship between water and sediment as well as co – ordinate the use of water for industry , daily life and ecology so as to enhance the river’s natural functions, improve the vitality of the river, and give full play to the overall efficiency of the reservoir. Furthermore, it can alleviate the current water shortage, too much water, water pollution, water features and other issues of the Yellow River, and is conducive to the goals of “no embankment breaching, no river course running dry, no pollution over standard, no riverbed rising” so as to promote the harmony of human with nature and guarantee the

comprehensive, coordinated and sustainable development for socio – economy and environmental resources.

It is an important measure for maintaining the health life of the Yellow River to strengthen the reservoir scientific operation, and it also plays an important role in the maintenance of reservoir's own health. We must strengthen the integrated regulation and adjustment for the whole basin tributaries multi – reservoir group and adhere to “the scientific development concept” with the people at the core and people living in harmony with water so as to coordinate socio – economic and ecological environment, strengthen the construction of laws and regulations system, standardize scheduling, Scheduling vigorously to improve the scientific operation level and the establishment and perfection of the Yellow River water and sediment control system with the reservoir ecological dispatching a technical system from the perspective of maintaining the sustainable development of watershed and river ecosystem health. Furthermore, we should strengthen the policies and regulations for ecological compensation mechanism, and enhance the integration of water and sediment on the management, coordination between water and sediment so as to give full play to the positive role of the reservoir. We should try to eliminate or reduce its negative effects and effectively control floods in flood season as well as reasonably make use of middle and normal flood and find the right time to construct so as to take good measures in water and sediment regulation, flood scheduling, pollution control, flood control and drought fighting and guarantee the river downstream of the reservoir to maintain the basic functions of basic ecology and constantly improve the water environment bearing capacity. So we can restore the sound river ecosystems to make it full of vigor and vitality to the benefit our future generations.

# Study on Wetland Protection in China

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**Abstract:** This paper expounds the major functions of wetlands, analyzes the main problems currently facing the protection of wetlands, and their causes, and then put forwards the corresponding countermeasures.

**Key words:** wetland protection, problems and countermeasures, China

Wetlands, forests and oceans are juxtaposed to be the three great ecosystems in the globe. Wetlands is an unique ecosystem formed by the interaction of waters and lands on earth with the greatest biodiversity in nature and is also one of the most important living environments of human beings with a huge potential for resources development and important functions in environment, society and economy. Wetlands is proud of its reputations of the kidney of the earth and the cradle of life because they not only provide various resources for man's life and work but also plays irreplaceable roles in flood control, runoff regulation, environmental protection, pollution control and protecting the diversity of genes of species, beautifying the environment and maintaining the ecological balance, etc. In recent years, the rapid development of economy and human activities has brought different destructions to wetlands and thus has deteriorated them little by little, decreased their environmental functions and biodiversity gradually. The increasingly prominent environmental problems such as environmental pollution, silt sedimentation, etc, have seriously threatened wetlands and their functions. Therefore it is imperative for human beings to protect and have a sustainable utilization of wetlands, to maintain a good ecological environment and to harmonize the relation between man and nature.

## 1 Survey of wetlands in China

China is located in the west to the Pacific, most of which belong to the subtropical monsoon climate and over which East Asian monsoon prevails. Therefore China has very clear seasons and a mild and humid climate, especially Yangtze River basin and its south areas, which have plenty of rainfall (over 1,100 mm/a averagely). Because of its advantageous of water and heat, China is affluent in biotic resources and diverse in ecosystem and is one of the countries with the richest wetlands. Wetlands in China (excluding rivers, ponds, and so on) cover an area of 65.94 million ha, accounting for 10% of the wetlands in the world, ranking fourth in the world and first in Asia. Wetlands in China are various in types, great in quantity, wide in distribution, remarkable in regional difference and rich in biodiversity, etc. Most of them are rivers, estuaries, lakes, marshes, coastal beaches, shallow offshore waters, reservoirs, ponds, paddyfields and so on. Natural wetlands (excluding rivers) have an area of about 25.94 million ha, including marshes of 11.97 million ha, natural lakes of about 9.1 million ha, intertidal coastal beaches of 2.17 million ha and shallow offshore waters of 2.7 million ha while artificial wetlands cover an area of approximately 40 million ha, including reservoirs of 2 million ha and paddy fields of 38 million ha. Except for rivers, Paddy fields are the largest in Chinese wetlands. According to Chinese standards of important wetlands, there are 173 state-level wetlands in China at present and 21 of them have been listed as international wetlands, which are important components of natural resources and

ecological environment and play significant roles in promoting sustainable development and protecting man's living environment.

## **2 Main functions of wetlands**

Wetlands are not only one of man's most important environmental capitals but also the ecosystem with richer biodiversity and higher productivity in nature. Wetlands' connection of water and land makes the coupling and interjunction of environmental factors in wetlands become complicated and their feedback on natural environment is also very great. Besides, wetlands provide human beings with a lot of means of production and means of subsistence such as food, raw materials and water resources. Therefore wetlands play important roles in ecology, economy and society. Wetlands can control flood, regulate runoff, control pollution, eliminate poison and purify water and is one of the areas with the strongest self-purification in natural environment. Wetlands play important roles in protecting environment, ecological equilibrium and conserving biodiversity and water resources, storing water, recharging groundwater, stabilizing coastal lines, controlling soil erosion, fighting against drought, purifying air, controlling climates and so on.

## **3 Main problems currently facing the protection of wetlands and their causes**

Because of population increasing and economy developing, wetlands are reclaimed, filled up, exploited excessively, and seriously polluted. All those result in the fact that the quantities, functions and benefits of natural wetlands are reduced sharply, that wetlands' conservation is seriously threatened and the ecological environment of wetlands are badly affected. Those are mainly manifested in the following ways: Firstly, the blind reclamation of wetlands leads to the reduction of wetlands in area and the ecological function of adjusting water storage. Secondly, the overuse of biotic resources results in the ecological unbalance of wetlands. Thirdly, the irrational utilization of wetlands water resources cannot guarantee the water use in ecological environment and thus many ecological problems will arise. Fourthly, the aggravation of wetlands pollution is extremely dangerous to wetlands' ecosystem. Fifthly, the aggravated soil erosion and silt sedimentation deteriorate the ecological environment. Sixthly, the expanding coastal erosion damages wetlands seriously. Seventhly, wetlands' degeneration reduces their biodiversity. In addition, the propaganda and education of wetlands protection are backward and the public are hardly aware of protecting wetlands. Furthermore, managements of wetlands protection always fall behind, which are usually embodied in the coarse management, the unsound organization, the imperfect legal system, lack of coordination mechanism, the weak fundamental research and the backward technology and management, shortage of funds on wetlands protection, the imperfect monitoring and evaluating system, which all place serious restraints on the healthy development of wetlands protection in China. From the major problems facing wetlands, the serious destruction of wetlands and the gradual deterioration of wetlands result from various factors, including both natural and human factors, but mainly from human activities. Natural changes' influences on ecological environment are very great and irreversible, such as storm floods, dry weathers, harmful winds and waves, etc. Human factors include man's excessive exploitation and utilization of wetlands, such as disordered reclamation and rehabilitation of wetlands, excessively cutting woods down, disordered drainage of sewage and so on. With the development of science and technology, human beings become more and more capable of changing nature and have greater influences on nature. Ecological destruction, water pollution, species extinction, the changes of the global weather are all closely related to man's activities.

## **4 Countermeasures for wetlands protection**

Wetlands are extremely helpful not only to social economy but also to water resources conservancy, water purification, water storage against drought, climate control, transformation of sediment into land and biodiversity protection, etc. A healthy ecological system of wetlands is very

important to the safety of the state – level ecological system and is also the key basis of the sustainable development of social economy. Wetlands protection plays a very important role on maintaining ecological balance, improving ecological environment, realizing the harmonious coexistence between man and nature and promoting the sustainable development of social economy. Therefore we should strengthen the propaganda and education concerning wetlands protection and ecological morals and have all kinds of active campaigns concerning wetlands protection so as to enhance the public's consciousness of protecting wetlands and create a favorable social environment for wetlands protection. We should adhere to the principles of science in the process of protecting the ecological balance, functions and biodiversity of wetlands and having a sustainable utilization of resources. We should persist in the principles of comprehensive protection, ecology first, giving prominence to key issues, reasonable utilization and sustainable development when making wetlands protection one of the basic national policies and setting up a lastingly effective mechanism of wetlands protection. We should also adopt various forceful measures, such as propaganda, administration, law, finance, science and technology, engineering, etc. in order to carry out overall and scientific management according to law. We should combine wetlands protection with their utilization and take full advantage of their ecological, economic and social benefits in the development of national economy so as to push the whole society develop towards higher production, wealthier life and better ecological environment until the harmonious coexistence between man and nature.

#### **4.1 Keeping five principles to ensure scientific protection**

(1) Based on the principle of precaution crucial, protection first and combining the rational utilization of wetlands with their protection, we should properly handle the relationship between the utilization and protection and the relationship between the utilization and the ecological system of waters, follow economic laws in nature faithfully, make a scientific and reasonable utilization of wetlands, eliminate the predatory utilization, namely, the blind and disordered utilization and combine wetlands utilization with their protection so that we can realize the self – discipline development to ensure healthy wetlands.

(2) Stick to the principle of harmonious coexistence between man and wetlands. We should properly handle the relationship between man and nature, between people and between interests of the part and those of the whole, strictly standardize man's behavior, protect the unity and diversity of wetlands, have a full understanding that protecting wetlands is to protect the ecological environment of water resources, to protect ourselves and to protect our home. Therefore wetlands protection is the common obligations and responsibilities of human beings. Everybody should be duty – bound to work together for more promising wetlands.

(3) Cling to the principle of the sustainable development. We should properly handle the relationship between the present and the future and the relationship between the immediate and long – term interests. We should be responsible for ourselves, our society, our country and descendants to keep up the sustainable development.

(4) Uphold the principle of the coordinated and harmonious development of all kinds of benefits with ecological one first. We should protect the biodiversity of wetlands and the unity of the structure and functions of wetlands ecosystem, properly handle the relationship between environmental resources, and the development of the social economy and the relationship among the use of water in ecology, life and production. We should, on the basis of the development of environmental resources, match the development of social economy with the bearing capacity of environmental resources so as to take a full advantage of the ecological, economic and social benefits of wetlands ecosystem.

(5) Keep to the principle of positioning on local conditions, unified planning and rational distribution, prioritizing key issues, holistic protection, integrating protection with rehabilitation and attaching equal importance to promoting what is beneficial and abolishing what is harmful. We should properly handle the relationship among nature protection, treatment and rehabilitation, the

relationship between treatment and management in order to restore and keep up the perfect ecosystem of wetlands.

## **4.2 Establishing and improving the five great systems, strengthening wetlands protection and improving the ecological environment**

### **4.2.1 The systems of organization management and protection supervision**

Wetlands are a kind of complicated ecosystem with many different types and levels and wetlands protection is such a huge systematic project covering a wide range of subjects, having great social benefits, involving several government departments and several branches of the national economy and serving the interests of many different parts that it needs the concerted efforts of all provinces, departments and the whole society. Therefore we should adhere to the principle of scientific development and have a correct view on achievements, keep up the harmony between the economic development and ecological protection and strictly exercise the unified management over wetlands according to the law and the science with the reach as a unit by establishing a forceful system of organization management and an efficient coordination mechanism for the state and local to know their duties and rights clearly and then to make efforts to do their duties. We should also establish a new order to manage wetlands protection by integrating the unified organization and coordination of the competent government department with the cooperation among several departments and combining reach management with region management and should encourage and guide people from all works to take an active part in the wetlands protection. At the same time, we should improve the quality of the staff managing wetlands and establish the system of the consociated law enforcement and the supervision by law – enforcement so as to upgrade their management over evaluating, approving and supervising the implementation of the projects on wetlands protection, development and utilization strictly according to law. We should also intensify the legislation on wetlands protection and its implementation, enforce the law strictly, handle, according to law, all kinds of cases breaking the law and regulation, resolutely stop the overuse and the irrational use of wetlands resources and adopt strong measures against the criminal activities such as the wanton appropriation and illegal damage of wetlands. All activities and projects developing wetlands must be evaluated on whether they will affect the environment. We should prohibit wetlands development activities that will be destructive in headwater regions, upstream regions, wetlands where soil erosion is severe, arid regions, wetlands inhabited by the state – protection rare animals and plants under and wetlands important to regional ecology and climate, put an end to hunting in wildlife sanctuaries and guarantee the safety of rare waterfowls. We should also strictly manage the projects of developing and utilizing wetlands in the light of the local conditions and restrict the development and utilization within the bearable limits of ecosystem so as to realize its sustainable development. Besides, we should also take full advantage of propaganda media, mass organizations, research institutes and the supervision of public opinion, strengthen management, supervision and coordination and call all possible forces into action so as to keep a good order in the protection and reasonable utilization of wetlands and do wetlands protection well.

### **4.2.2 The system of relevant policies, laws and regulations**

Chinese laws and regulations on wetlands protection are still imperfect. Therefore we should stipulate the Protection Laws for Wetlands and the corresponding system of laws and regulations as soon as possible, formulate policies, principles and regulations of conduct for protecting, developing and utilizing wetlands in the forms of laws and regulations, clearly define the limits of organizations of all trades at all levels and their management divisions, stipulate management procedures, approaches and procedures of dealing with legal offenses, etc. In order to provide fundamental standards of behavior for managers in charge of the protection and reasonable utilization of wetlands and wetlands users. We should also coordinate the comprehensive management of wetlands and water resources, environmental planning, biodiversity protection, the national land utilization planning, international agreement and wetlands legislation so as to place wetlands protection on a legal track with rules and regulations to go by.

At the same time, we should stipulate and perfect Chinese relevant policies on wetlands protection as soon as possible. Under the overall economic operational mechanism of the national land utilization, we should establish and improve the system of economic policies to encourage and guide people to protect and reasonably utilize wetlands and restrict the damage of wetlands, such as the policy of developing and utilizing wetlands by financial compensation and managing ecological restoration, economic policies of effectively integrating water resources with wetlands protection, increasing the cost of occupying the natural wetlands, formulating economic policies on limiting the development of natural wetlands and policies on the economic assistance to artificial wetlands treatment and development and setting up the mechanism to encourage collective and individual funds raising or donations and to encourage the public to participate in wetlands protection, etc. We should also formulate the policies of encourage people to economize natural wetlands resources, attach top priority to protect wetlands biodiversity in developing departments and solve problems met in investment, credits, project approval and initiation and technological support according to relevant policies so as to ensure the coordinated development of wetlands resources protection and economy.

#### 4.2.3 The system of projects

Projects on wetlands protection are the forceful measures and the important guarantee to protect wetlands. Proceeding from the real situations of Chinese wetlands, we should carry out important protection and construction in some key wetlands, especially some major international and national wetlands and their functional areas, give priority to the model projects of protecting, treating and restoring some typical and urgent wetlands and pay special attention to the protection and restoration of ecological functions according to the principle of integrating parts with the whole, focusing on key points, paying equal attention to protection and restoration and the principle of the overall protection and models first and based on the overall planning of Chinese wetlands protection, restoration and reasonable utilization and the construction of ecological tourism and urban wetlands parks. In accordance with the National Planning for Projects on Protecting Wetlands, the government will invest to construct 225 wetlands protection areas besides the planned 90 from 2004 to 2010. Among the 225 wetlands protection areas, 45 are key state level and 30 major international level and 0.715 million ha of wetlands and 0.383 million ha of wildlife habitats will be restored. By 2030, China will complete the ecological improvement and restoration of 1.4 million ha wetlands, set up 53 state-level model areas of protecting and rationally utilizing wetlands, has 713 state-level wetlands protection areas and 80 important international wetlands and has over 90% of natural wetlands protected so as to bring the functions and benefits of wetlands ecosystem into full play and realize the sustainable utilization of wetlands resources.

Based on the construction of Chinese wetlands protection, management, scientific research and supervision, we should integrate systematic projects and comprehensive management to step up the organization and implementation of wetlands planning and ensure to carry out and accomplish the objectives and tasks of protecting wetlands according to schedules. We should take forceful measures, make vigorous efforts to promote emergency protection and build up some emergency nature reserves in some weak ecological wetlands, enlarge the area of wetlands protection and actively carry out the wetlands protection and rational utilization models and do some key model projects well to guide the whole construction of wetlands protection.

Local governments should pay great attention to the construction of projects on wetlands protection, bring wetlands protection into their planning for local ecological construction and the development of economy and society, strictly carry out the system of evaluating whether the construction project of developing wetlands will affect environment and improve their organization leadership and supervision management to strengthen wetlands protection and create a beautifully aquatic and ecological environment. In addition, supported by nature reserves of all types of wetlands, we should take full advantage of and exploit all kinds of tourism resources, vigorously develop ecological tourism and promote the coordinated development between wetlands ecological tourism and wetlands protection to realize the harmonious coexistence between man and nature.



#### 4.2.4 The system of science, technology, monitoring and evaluation

Strengthening the scientific study of wetlands is the main approach to know and understand wetlands and also a very important guarantee to promote wetlands protection and their sustainable utilization. So far, the fundamental researches on wetlands in China are rather weak and vague. For example, many characteristics of wetlands are still unclear. Therefore both fundamental and applied researches are needed to have a comprehensive, deep and systematic knowledge of Chinese wetlands types, characteristics, functions, values, dynamic changes, etc. so that wetlands protection and rational utilization can be based on science. In addition, to set up science base for the planning design of wetlands protection and rational utilization, the index system for evaluating wetlands quality, functions and benefits should be established, the potential for developing wetlands should be exploited and the threshold and ecological risk of wetlands development should be analyzed according to the characteristics, ability, range and threshold of their responses to the physical environment. At the same time, in order to raise the level of wetlands protection to a great degree, we should establish and perfect the management mechanism and organization system of popularization of wetlands protection and their rational utilization technology, energetically promote popularization and exchange of wetlands protection, rational utilization and comprehensive management technology, etc., formulate the overall plan for preservation of various species of wild plants and animals and carry it out step by step, work hard to study and popularize advanced wetlands biodiversity protection, pollution control technology, etc., strengthen international cooperation in all-round import of advanced technology, management experience and funds, including the bilateral, multilateral, governmental and non-governmental cooperation and take an active part in prior cooperative projects of wetlands protection.

In order to carry out the scientific protection and utilization of wetlands resources, we should make clear the overall situation of wetlands in China, earnestly plan wetlands protection with the reach as unit, classify and evaluate wetlands in the whole country and establish the information and data management system and the monitoring system of wetlands resources in the whole country to monitor changes of wetlands water quality, groundwater table, plant communities, soil nutrients and soil deterioration and evaluate wetlands ecological changes in time so that wetlands hydrological changes can be controlled within their threshold. By means of monitoring networks, we can also master developing changes and trends of all types of wetlands, provide regular monitoring data and report which can be used as a basis for the government at all levels to make decisions, to evaluate the hydraulic engineering facilities' influence on ecology, establish guarantee mechanism of replenishing natural wetlands and the systems of evaluating wetlands influences on environment and approving projects, perfect evaluation standards, carry out the evaluation of wetlands development influences on ecology and benefits on environment in advance and develop the scientific study on the relevant theories and methods of evaluating wetlands influences on environment.

Through investigation, monitor, evaluation and experts' demonstration, we can evaluate Chinese potential for developing and utilizing wetlands scientifically, define the greatest developing and utilizing limit of every type of wetlands, important value-added wetlands resources for prior utilization, classification of utilizations and the intensity and methods of wetlands development and rational utilization, can properly plan wetlands development and rational use, try to establish the permission system of natural wetlands development and know wetlands developments in time to provide scientific bases for wetlands protection and utilization.

#### 4.2.5 Support system for investment

Wetlands protection is such an inter-departmental, multidisciplinary, comprehensive and systematic project that it must be invested through diversified channels and in diversified ways and levels. The governmental investment is the main channel of funds for wetlands protection. The local government at all levels should list wetlands protection in the planning of developing the national economy and society to guarantee that wetlands protection can be carried out all over the country. At the same time, we should won extensive international support, encourage all kinds of investors to invest any money on wetlands protection and collect funds from society at large by means of standardizing the use of collective funds raising and individual donations so as to establish an

investment mechanism of integrating national funds for wetlands protection with the investment of people from all works of life on wetlands protection and provide a forceful investment support for wetlands protection.

### **4.3 Taking wetland protection as a core, strengthening managements to maintain good water ecological environment**

#### **4.3.1 Strengthening the management of water resources and establishing the security mechanism of water consumption in wetland**

Water is an important component of wetland. The total amount of freshwater resources in China is 2.8 trillion m<sup>3</sup>, but only about 40% ~ 50% can be utilized. As a nation with an acute shortage of water, Chinese per capita water – consumption is equivalent to one quarter of the world consumption, ranking number 109 in the world. Therefore we should endeavor to make water – saving become a common practice in our society. Specifically speaking, management system of water resources must be regulated by the government, guided by the market, participated by the public and based on the theory of water rights and water markets. Meanwhile, saving water system must rely on economic means:

Firstly, we should strengthen the investigation and planning for water resources, clarify the initial water rights, determine and carry out macro – control target and rated target in a microscopic view on each level, constitute trading market regulation and formulate water rights market, implement compensated transfer of water rights, improve the system of water prices and adjust its price reasonably. In brief, various kinds of measures can be taken together to strengthen the management of water resources. Besides, by making full use of surface water and developing groundwater, as well as through the implementation of water – saving activities, we will improve the efficiency of water utilization.

Secondly, we should further change the mode of production and consumption to take into consideration of social, economical and ecological benefit. Ecological and water conservancy construction should be emphasized and flood diversion and water storage projects should be built. Furthermore, sufficient water and its quality must be guaranteed to maintain the moisture of the wetland.

Thirdly, we should continue to readjust the water – use structure and the mode of economic growth, popularize modern technology of water – saving, entail water forming the base of economic development. Meanwhile, it is also important to keep the supply and demand of water resources balanced. It is well known to us that the development of water resources exerts diverse influences on the ecological environment of wetland and creatures living in it, which must be carefully estimated and monitored. Most favorable mode of water allocation should be carried out and security mechanism of water consumption in wetland be established. All these measures mentioned above aims to maintain the natural conditions in wetland and its ecological functions, popularize the utilization of water resources scientifically and further to make overall plans about the water for ecology, life and productive use so as to ensure adequate supply for wetland.

#### **4.3.2 Strengthen the administration of water environment and prevent its pollution according to laws so as to improve its carrying capacity and ensure wetlands healthy and drinking water safty**

Water environment can provide water, living and tourist resources, and it can also be used to generate electricity, shipping and draining water. Currently, the pollution of water environment has become increasingly severe owing to frequent human activities. Thus environmental management system is to be improved, that is, environment protecting department is supposed to unify their supervision and management, and some related departments ought to assume their own responsibilities. At the same time, system of controlling pollutant discharge amount and environment impact assessment is to be carried out carefully and how much influence exerted on the ecological system by human beings should also be estimated. We ought to find the sources and factors threatening, destroying and polluting the wetland, study and evaluate its ecology influence of

reclaiming, inning, huge project or other activities. As a result, environment impact assessment can prevent artificial and large – scale destruction to the wetland ecological system so as to utilize and protect it better.

In addition, system of pollution discharge permit should be established, and environmental quality standard of water as well as standard of pollutant discharge in every region. The function of dilution and self – purification of river and environmental capacity are also to be studied. We should scientifically strengthen our administration based on law, bring the pollution of wetland under control and prevent pollutant discharging in seas, lakes or rivers in a planned way to make it reach the specified standards by the prescribed time.

We must restrict and penalize all department, enterprise and unit with exceeding sewage discharge and demand them to rectify and reform within a specified time. Moreover we must control strictly the discharge of the three wastes from some construction project and industrial enterprise with excessive pollution and consumption to reduce pesticide and fertilizer’s harm to wetland. We should firmly take the measures of “closing, pausing, merging, shifting and moving” to those units polluting heavily environment, actively put into effect environment – friendly production and circular economy and build pollution compensation mechanism. Complying with the principle of “who develops, who preserves, who exploits and who compensates”, we should take compensation measure in time to restore wetland destruction resulted from development and exploitation, strictly controlling environment destruction at source and process in new construction project, practically strengthening water pollution’s controlling and prevention to further improve water ecology environment.

#### **4.3.3 Strengthen preservation and management ecologically and building green hills and green waters to ensure security of ecology and grain food**

Wetland plays an important role in preserving ecological environment and promoting social and economical development in that many ecological functions are reflected by wetland systematic functions. Wetland ecological system is fragile and once being damaged, it is irreversible, and it will take a rather long time to harness and restore the wetland at an enormous cost. If mankind destroys recklessly wetland resource with immediate and partial interests, they will suffer tremendous losses and crucial revenge from nature which will bring disaster to descendants.

To curb ecological environment deteriorating and protect finite wetland resource, we must take action as soon as possible to further administer synthetically, build ecological agriculture, plant forest for conservation of ecology and water supply, retreat the land for forestry, grass and lake, change the way of land utilization preventing water loss and soil erosion. We should build actively reservation district, suspending hunting area and governing area ecologically and make it clear that state administers land and natural resource uniformly, thoroughly putting an end to discharging arbitrarily mill tailings, slag, waste rock and waste water and preventing and controlling wetland from geological and ocean harm. It is indispensable that to draw up scientific program to exploitation and utilization of wetland and to build wetland’s ecological environment impact assessment system, ecological compensation mechanism, social supervision mechanism and harmonious management mechanism focusing on artificially ecological destruction and strengthening resource development’s ecological reservation supervision. In addition, we should implement the sort management of wetland resource reservation and reasonable exploitation under the united planning, restore degenerate wetland, rebuild demonstration area, cultivate special marine product and plant new agricultural product in wetland on purpose of increasing the efficiency of resource utilization, gradually realizing sustainable utilization of wetland resource and ensuring ecological and grain security.

# Sustaining Healthy Life of Yellow River through Flood Utilization

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**Abstract:** The problems of the Yellow River are fundamentally due to its characteristics of less water but much sediment, imbalance of water and sediment, and concentration of limited water during flood seasons. There exists channel sedimentation and waste of floodwater resources due to sediment transporting capacity of floodwater not being fully utilized. So, utilizing limited water (especially, floodwater resources) is the key to solve the problems of the river. “Sustaining the healthy life of the Yellow River” is a new concept and objective of river control, and “no dyke breach, no dry river, no over standard water pollution and no increased sedimentation in the riverbed” are four symbols. They interact and supplement each other. First, measures can be taken to regulate stored excessive water synthetically to deal with water shortage and no-flow during non-flow seasons, such as raising limited water level of reservoirs during flood seasons, controlling limited water level during flood seasons dynamically, or “impounding floodwater” in storage and detention basins in the mid- and downstream areas. Second, surplus water obtained from discharging water before flood seasons and runoff during flood seasons can be utilized to regulate water and sediment, which can mitigate sedimentation in riverbeds of the downstream and broaden conveyance capacity of the channels of the downstream to prevent dykes from breaching. Third, “storing water in high-flow periods to meet demands in low-flow periods” will keep the downstream from no-flow and will promote self-purification capacity of water in the downstream to prevent water pollution. Consequently, man and flood can co-exist harmoniously, and the river will in benign ecological cycle. Before the South-North Water Transfer Project via the western course come into operation, the Yellow River can get no water supply from other water bodies. Flood utilization will act to “increase income and decrease expenditure”. Measures should be taken to utilize floodwater resources. Consequently, the healthy life of the river will be sustained.

**Key words:** flood utilization, impounding floodwater, sediment regulation, drawing river water to wash out sewage, healthy life

## 1 Introduction

“Sustaining the healthy life of the Yellow River” is a new concept and an ultimate objective of the river control, and “no dyke breach, no dry river, no over standard water pollution and no increasing sedimentation in the riverbed” are four symbols of the objective (Li Guoying, 2005). It is a complicated system engineering to implement the objective; so, measures of treating both symptom & root cause and comprehensive treatment should be adopted. The problems of the Yellow River are fundamentally due to its characteristics of less water but much sediment, the imbalance of water and sediment, and concentration of limited water during flood seasons (from July to October), even during some flood periods; which results in flood being controlled during flood seasons or no-flow being prevented during non-flow seasons. On the other hand, there exists channel sedimentation and waste of floodwater resources due to the sediment transporting capacity of floodwater being not fully utilized. So, making full use of the limited water (especially, floodwater resources) is the key to solve the problems of the Yellow River.

Flood utilization indicates that based on the precondition of sustainable development of water

resources, reservoirs, lakes, the storage and detention basins and projects of groundwater recharge are utilized to improve rate of utilization of floodwater through impounding floodwater and mitigating floodwater quantity of entrance sea in accordance with regional conditions of economic development and hydrology characteristics. In the process, existing water conservancy projects, modern weather forecast and scientific management guarantee safety of reservoirs and lower reaches of a river, and ecological environment is not destroyed.

### 3 Thought train of sustaining healthy life of the Yellow River through flood utilization

“Sustaining the healthy life of the Yellow River” consists of four objectives. Namely, “no dyke breach, no dry river, no over standard water pollution and no increased sedimentation in the riverbed”. The four are independent on the surface; in fact, they interact, constrict mutually and supplement each other.

Thought train of sustaining healthy life of the Yellow River through flood utilization is shown as Fig. 1. Firstly, measures can be taken to regulate the stored excessive water synthetically to deal with water shortage and no-flow during non-flood seasons, such as raising the limited water level of reservoirs in the mainstream and tributaries during flood seasons, controlling the limited water level during flood seasons dynamically, or “impounding floodwater” in the low-lying land areas and the storage and detention basins in the mid- and down-streams. Secondly, surplus water obtained from discharging water before flood seasons and runoff during flood seasons can be utilized to regulate water and sediment as the situation demands, which can mitigate sedimentation in riverbeds of the down-stream and broaden conveyance capacity of the channels of the down-stream to prevent dykes from breaching. Thirdly, “storing water in high-flow periods to meet demands in low-flow periods” will keep the down-stream from no-flow, will solve the problem of water shortage in the areas along the river to some extent, and will promote self-purification capacity of water in the down-stream to keep the water from pollution. Consequently, man and flood can co-exist harmoniously, and the Yellow River will in benign ecological cycle.

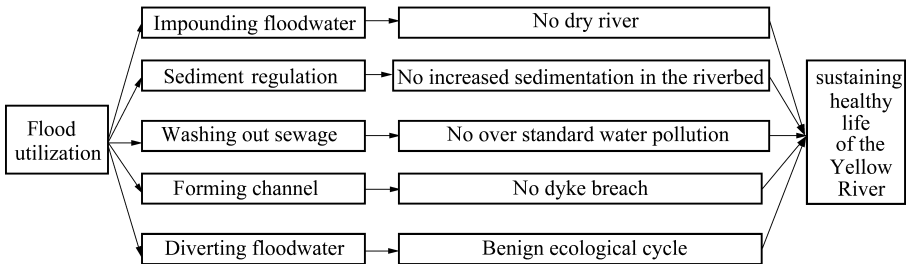


Fig. 1 Thought train of flood utilization

### 3 Feasibility analysis of flood utilization in the Yellow River

#### 3.1 Preventing the river from dry river through “impounding floodwater”

The perennial average runoff of the Yellow River is  $580 \times 10^9 \text{ m}^3$ . With rapid development of economy and society, water consumption continues to increase. Up to now, quantity of consumption in industry and agriculture has increased from  $120 \times 10^9 \text{ m}^3$  to  $307 \times 10^9 \text{ m}^3$  in the 1950 s, which results in severe dry river in the downstream (Cheng Jinhao et al., 1998). In 28 years (from 1972 to 1999), dry river in the downstream has appeared in 21 years, and the period of dry river adds up to 1,050 days. After 1999, regulating floodwater synthetically in the main stream has alleviated dry river to some extent. Nevertheless, the problem of water shortage and dry river is not solved fundamentally because the Yellow River basin is a water shortage area. Statistics suggests that the

perennial average runoff of emptying into the sea of the Yellow River is  $324.53 \times 10^9 \text{ m}^3$  from 1950 to 2003; while the runoff during flood seasons is  $196.89 \times 10^9 \text{ m}^3$ , which is 60.7% of the former (Liu Yongsheng et al., 2005). If the flood resources emptying into sea are utilized, water shortage and dry river of the Yellow River will be alleviated to a great extent.

To take full advantage of flood resources in flood seasons of the Yellow River, two problems to need be solved. Firstly, the existing manner of reservoir regulation, regulating floodwater at stationary limited water level of reservoirs in specific time, should be altered to transfer benefit of preventing flood into benefit of beneficial use (Zhong Ping, 2002). Secondly, potential of reservoir operation based on forecast can be utilized to impound water in reservoirs during flood seasons safely and effectively depending on technology progress in weather forecast and flood prediction. There are two methods to lift limited water level of reservoirs appropriately. On one hand, limited water level of reservoirs can be lifted propriety due to tendency of incoming flow of the Yellow River in recent years is less than before. On other hand, limited water level of water conservancy projects in the mainstream and tributaries of the Yellow River can be managed dynamically, which can impound more floodwater during post – flood seasons to improve assurance factor of impounding of reservoirs during non – flood seasons and to make full use of integrated benefits of reservoir. Thus, water supply to the downstream can be provided persistently during low flow seasons to ensure water supply in the period of water shortage. On the another hand, dry river will be prevented to sustain healthy life of the Yellow River. The case study of the Sanmenxia Reservoir in the middle reach of the Yellow River provides analysis of feasibility and benefits of impounding floodwater. The limited water level of the Sanmenxia Reservoir is lifted to 306m and 307 m respectively; accordingly, the water level before snowmelt flood is lifted appropriately too. Consequently, there are 9 schemes shown as Table 1.

**Table 1 The schemes of lifting limited water level of Sanmenxia Reservoir**

scheme	Non – flood seasons(m)		Flood seasons(m)	
	WL before snow flood	Top WL	Lowest WLL	Imited WL
1	310	310	305	305
2	312	319	298	306
3	312	319	298	307
4	315	320	298	307
5	312	319	298	305
6	Emptying operation all year round			
7	313	319	298	307
8	313	319	296	307
9	313	319	Emptying operation during July ~ September	

The results of the 9 schemes (Yang Qing'an et al., 1995) suggest that the Sanmenxia Reservoir can store extra pondage of  $4 \times 10^9 \sim 5 \times 10^9 \text{ m}^3$  after limited water level during flood seasons is lifted and water level before snowmelt flood is altered appropriately; accordingly, compared with the current operation style, more economic and social benefits will be produced (for instance, extra water supply to the areas in the downstream can provide economic benefits of  $20 \times 10^7 \sim 50 \times 10^7$  yuan RMB (Feng Feng, 2005)). If the method of lifting or dynamically managing limited water level during flood seasons is used in the other reservoirs in the mainstream and tributaries of the Yellow River, more water will be impounded, consequently, water shortage and

dry river in the downstream of the Yellow River will be mitigated to a great extent.

**Table 2 Estimation of schemes of Sanmenxia Reservoir**

Scheme	Tongguan elevation at the end of flood seasons m (m)	Average generating capacity pre year ( $10^9$ kWh)			Pondage ( $m^3$ )		
		Non – flood seasons	Flood seasons	Sum	Non – flood seasons	Flood seasons	Sum
1	328.34	9.07	2.14	11.21	0.984	0.195	1.179
2	328.30	10.10	1.68	11.78	4.62	0.275	4.895
3	328.35	10.10	1.77	11.87	4.62	0.422	5.052
4	328.60	10.77	1.78	12.55	4.63	0.422	5.052
5	328.25	10.10	1.61	11.71	4.62	0.195	4.815
6	327.85	0	0	0	0	0.002	0.002
7	328.50	11.58	0.98	12.56	4.62	0.422	5.042
8	328.36	11.60	0.96	12.56	4.62	0.422	5.042
9	328.34	11.60	0	11.60	4.62	0.002	4.462

### 3.2 No increased sedimentation in the riverbed through sediment regulation

The channel of main stream in the downstream of the Yellow River has shrunk severely in recent decades, which results in decreasing flow capacity. When natural flood occurs, runoff is so little that water is out of harmony with sediment, so, the channel of mainstream is silted; or runoff is too much to flood land; or floodwater of little sediment flows into sea, which leads to waste of hydroenergy and water resources. Consequently, the healthy life of the downstream will disappear. If motive power from floodwater is utilized to regulate water and sediment transmission, the process of water and sediment in harmonious style with runoff, silt content and grain composition can be modelled. Thus, the channel of main stream in the downstream of the Yellow River will be kept from deterioration; moreover, its healthy life will be recovered gradually and will be sustained fundamentally. Regulating water and sediment will solve the problem of sedimentation in the Yellow River effectively in a long – term. The 5 tests of water and sediment regulation conducted on the Yellow River have implemented successfully from 2002 to 2006.

As Table 3 shows, all the former 3 tests of water and sediment regulation is conducted in flood season. In accordance with discarding water above the limited water level and forecast of water and sediment in the coming days, flood peak is produced artificially to regulate sediment to the utmost extent (Li Guoying et al., 2003). The problems of riverway deterioration in the downstream and “second level perched river” have been solved in some degree after the 3 tests of water and sediment regulation (Li Guoying et al., 2003). And artificial disturbance to sediment can enlarge the channel of main stream in “bottleneck” sections with less capability of discharging flood in the Yellow River. Effectiveness of erosion is significant: average erosion depth is 0.66 m and runoff of flat shoal increases 440 ~ 550  $m^3/s$  (Li Guoying et al., 2003). The deposited silt at the siltation delta in the Xiaolangdi Reservoir region is shaped to turbidity current through water regulation conducted on multistorage system in the middle reach, so, reservoir capacity of sediment trapping is resumed partly and lifespan of reservoirs in sediment trapping is extended. Consequently, discarding water above the limited water level and runoff for producing flood peak can be utilized efficiently to regulate water and sediment, thus, sedimentation in the riverbed will not be raised.

**Table 3 Control data in the three tests of water and sediment regulation conducted on Yellow River**

Control data	The first test	The second test	The third test
Benginng and ending data	9AM 7. 4 2002 ~9AM 7. 15 2002	9AM 9. 6 2003 ~8PM 9. 18 2003	9AM 6. 19 2004 ~ 8AM 7. 13 2004
Duration ( day )	11	12. 4	24 ( actually19)
Water discharge ( $10^9 \text{ m}^3$ )	26. 61	27. 49	46. 80
Sediment discharge( $10^9 \text{ t}$ )	0. 664	1. 207	1. 105
Net wash load in downstream in the lower reach ( $10^9 \text{ t}$ )	0. 362	0. 456	0. 665
Sediment discharge in Xiaoliangdi Reservior( $10^9 \text{ t}$ )	0. 302	0. 740	0. 440
Total wash load in the river before Lijing monitoring site( $10^9 \text{ t}$ )	0. 334	0. 456	0. 655
Erosion intensity ( $10^5 \text{ t/m}^3$ )	4. 4	5. 8	8. 8
Erosion efficiency per Unit Water ( $\text{t/m}^3$ )	0. 012, 6	0. 016, 6	0. 013, 9

### 3.3 No over standard water pollution through drawing river water to wash out sewage

The pollution of the Yellw River can be alleviated through drawing river water to wash out sewage. Water supply cannot meet water demand due to frequent dry river and durative reduction of water entering into sea. Water is polluted badly and ecological environment is worsened. Consequently, wetland and biodiversity in the river mouth are threatened severely. On the other hand, channel of main stream is silted gradually, which reduces capacity of flow and does harm to flood preventing. Big runoff with good quality of floodwater can be used to dilute polluted wate in rivers, lakes and reserviors and to exchange water body, which can improve water quality and better ecological environment in the Yellow River basin ( Zhang Ouyang et al. , 2005 ). Flood water also can desalt sea water in areas of adjacent sea.

### 3.4 Preventing dykes from breaching through “forming channel”

As Table 4 shows, flow capacity of channel of main stream in the downstream was only 1,800  $\text{m}^3/\text{s}$  before the first test of water and sediment regulation in July, 2002; whereas the capacity has increased to about 3,000  $\text{m}^3/\text{s}$  after the former 3 tests. If more other tests of water and sediment regulation are conducted on the Yellow River, there will be a comparatively narrow and deep channel of main stream in the downstream. Consequently, river regime is steady under restriction of river control works. Ordinary flood, regulated by reserviors in the middle reach to flow in the channel of main stream, can not lead to floodplain. Or, if major flood or extraordinary flood occurs in the downstream, levees are prevented from breaking because some flood can impounded in floodplain, some flood is utilized to nourish beach and to wash silt in main channle and the other is controlled by standardization embankment.



**Table 4 Flow capacity and bankfull water level at hydrologic stations in the downstream after the three tests of water and sediment regulation conducted on Yellow River**

Station	Before	After the first test		After the second test		After the third test	
	test (m <sup>3</sup> /s)	Flow capacity (m <sup>3</sup> /s)	Bankfull WL (m)	Flow capacity (m <sup>3</sup> /s)	Bankfull WL (m)	Flow capacity (m <sup>3</sup> /s)	Bankfull WL (m)
Huayuan kou	3,400	3,700	93.75	4,450	93.88	4,340	92.34
Jiahetian	2,900	2,900	77.41	3,300	77.40	3,840	75.90
Gaocun	1,750	2,800	63.21	2,750	63.40	3,210	62.27
Sunko	2,070	1,890	48.52	2,300	48.45	2,460	47.64
Aishan	3,300	3,200	42.30	2,850	41.65	2,820	40.40
Luokou	2,800	2,960	31.40	3,200	31.40	3,120	29.68
Lijin	3,500	3,500	14.39	3,350	14.24	3,310	12.58

### 3.5 Realizing benign ecological cycle through “diverting floodwater for siltation”

Engineering of flood control and irrigation in the Yellow River guarantee flood utilization in safe and reasonable way. When major flood of certain magnitude or flood with little sediment occurs in the downstream, it can be used to renovate the ecological environment to irrigate farms through flood control works. And, floodwater also can be transported to complement ground water in Irrigation areas diverting water from the Yellow River by control of reservoirs in the upstream which can delay and slow flood (Feng Feng et al., 2005). On the other hand, middle and small flood can renovate the ecological environment to sustain functions of flood diversion and detention of flood storage and detention basins. And middle and small flood also can replenish and ground water resource and can supply emergency diversion water to wetlands in areas of river banks and the river mouth. Consequently, ecological environment will be kept from pollution and biodiversity in wetlands can be protected. Thus, benign ecocycle can be achieved.

## 4 Conclusions

Flood utilization can provide more water for environmental, industrial and domestic purposes, which originates from decrease of water entering into sea and water flowing to other countries. Accordingly, it can provide sufficient water to meet the demands of building a well – off society in an all – round way. Before the South – North Water Transfer Project via the western course is in operation, the Yellow River can get no water supply from the other; so, floodwater utilization will “increase income and decrease expenditure”. We can take measures such as accumulating floodwater, adjusting sediment, drawing river water to wash out sewage, forming channel, diverting floodwater for siltation and so on, to make use of the floodwater. In this way, we can solve a series of problems (for example, much sediment but less water) to sustain healthy life of the Yellow River.

### Acknowledgements

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# Role of Xiaolangdi Reservoir Operation in Keeping the Yellow River Estuary Healthy\*

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**Abstract:** With the recorded data of hydrology, sediment and large cross sections of the Yellow River estuary, the authors analyzed the changes in flow and sediment regimes at the estuary, the capacities of the channel for flow and sediment conveyance, eco – environment, and the others. The research results, among others, show that long – lasting low regimes of flow and sediment in the period from 1986 to 1999, prior to the operation of the Xiaolangdi Reservoir, threatened the estuarine life, while harmonious flow and sediment condition, which was made by the regulation of the reservoir since 1999, has eroded the estuarine channel bottom by more than 1 m, increased the capacities of the channel for flow and sediment conveyance, stopped the river drying – up events from happening, and improved eco – environment in the estuary.

**Key words:** Yellow River estuary, healthy life, water and sediment collocation coefficient, discharging capacity, eco – environment

## 1 The water and sediment conditions in estuary improved

### 1.1 Sediment concentration dropped dramatically and the discharge magnitude for sediment transport increased

Thanks to the sediment trapping by the Xiaolangdi Reservoir in its initial operation stage, the sediment concentration in the Lower Yellow River (LYR) was dropped dramatically, and the sediment contained in the water running into the Yellow River estuary was still decreased remarkably, notwithstanding the recovery by flushing a few hundred kilometers of the riverbed along the LYR. For the same series of both less flow and sediment, from 1986 to 1999 before the operation of the Xiaolangdi Reservoir, the sediment concentration in flood season and the average annual sediment concentration of Lijin Station were 38.1 kg/m<sup>3</sup> and 27.0 kg/m<sup>3</sup> respectively. From 2000 to 2004, after its operation, those declined to 19.7 kg/m<sup>3</sup> and 13.9 kg/m<sup>3</sup> respectively.

In the 1986 to 1999 series, the flow discharges of 1,000 m<sup>3</sup>/s to 3,000 m<sup>3</sup>/s are the main discharge magnitude for sediment transport (71.88% of sediment carried out). In the 2000 to 2004 series, the main discharge magnitude for sediment transport is 2,000 m<sup>3</sup>/s to 3,000 m<sup>3</sup>/s, showing an increase trend.

### 1.2 Relatively favorable water and sediment collocation

In the past, people used to express the effect of water and sediment collocation by incoming sediment coefficient, however, the coefficient can not distinguish the years with high flow and much sediment from the years with low flow and less sediment. Thus the index that can show the water and sediment allocation characteristic is developed as:

$$K = (Q/Q_{\text{多}})(S_{\text{多}}/S)\exp(W_2/W_{\text{汛}})$$

where:  $K$  is the water and sediment allocation coefficient;  $Q$  and  $Q_{\text{多}}$  are the average discharge in flood season and perennial average respectively;  $S$  and  $S_{\text{多}}$  are the average sediment concentration in flood season and perennial average respectively;  $W_2$  is the runoff when the discharge in flood season above 2,000 m<sup>3</sup>/s;  $W_{\text{汛}}$  is the discharge in flood season. The bigger  $K$  is, the more favorable the

water and sediment allocation will be.

Fig. 1 shows the coefficient in each flood season. The value of  $K$  in high flow year such as 1961 to 1964, 1967, 1976 and 1983 to 1984 was big and the water and sediment allocation was favorable. From 1986 to 1999 the water and sediment allocation coefficient in flood season was obviously smaller than that of the previous years. Except 1989 and 1996, the value of  $K$  in the other flood seasons were all smaller than 1, the water and sediment allocation was unfavorable. Compared with the period from 1986 to 1999, the value of  $K$  in flood season after the operation of the Xiaolangdi Reservoir in 2003, was becoming bigger and the water and sediment allocation was relatively favorable.

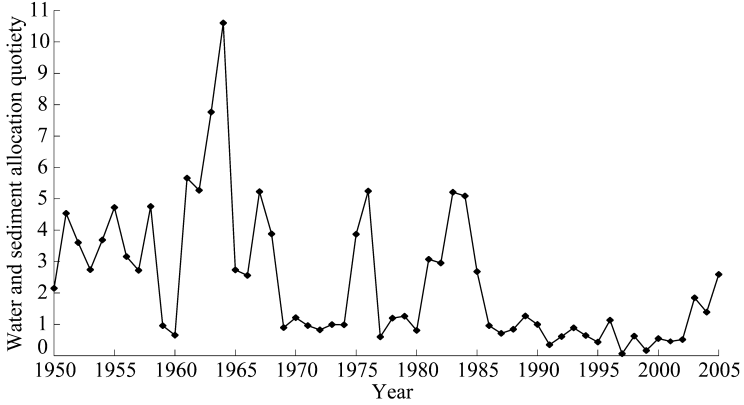


Fig. 1 The process of water and sediment allocation change

## 2 The restraining function to riverbed elevation was frankly

### 2.1 The estuary channel was scoured clearly

Fig. 2 shows the layout of scour amount below Lijin in the period from October 1985 to October 2005. From which it can be seen that from Oct. 1985 to May 1996, the river channel was silted and the most severely silted part was the section between Yuwa and Qing 3. During the period from the operation of the Xiaolangdi Reservoir and the river channel change of Qing 8 in 1996, the scour occurred in the LYR channel and siltation on the Upper Yellow River (UYR) in normal that had the tracing and scouring source characteristic. After the operation of the Xiaolangdi Reservoir, the whole river channel was scoured and the most severely affected part was still the section between Yuwa and Qing 3. From the 1999 flood season to Oct. 2005, after the operation of the Xiaolangdi Reservoir, the section between Lijin and Qing7 was scoured with a total amount of 45.28 billion  $m^3$ , in which the section above Yuwa was 19.35 million  $m^3$ , Yuwa to Qing 3 was 25.56 million  $m^3$  and below Qing 3 was 37 million  $m^3$ .

The scour amount of the estuary channel has the closed relationship with water and sediment conditions, channel boundary condition and estuary erosion datum plane. The water and sediment conditions can be expressed by water and sediment allocation coefficient; the channel boundary condition can be indirectly reflected by the previous scouring and siltation amount; the stretched length of the estuary by silting can express the erosion datum plane. With the analyzing of the data for Qingshuigou in the period of flow alone, the scour amount can be displayed as following: (relative coefficient is 0.83)

$$\Delta W_s = 1.5K^{-0.033,8} \left( \sum W_s + 1 \right)^{-0.051,9} e^{0.199C} - 2$$

where:  $\Delta W_s$  is the scour amount in the section between Lijin and Qing7 in 0.1 billion  $m^3$ ;  $\sum W_s$  is the total scour amount in five consecutive years in 0.1 billion  $m^3$ ;  $K$  is the water and sediment

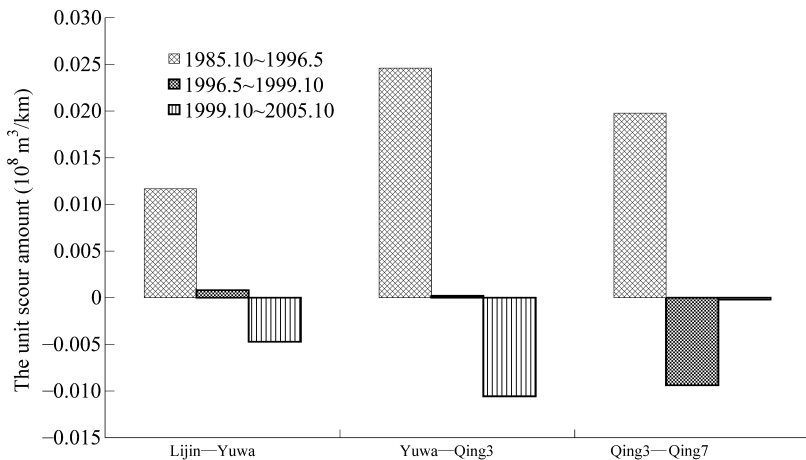


Fig. 2 Layout of scour amount in different periods

allocation coefficient in flood season;  $C$  is the relative channel length below Xihekou in km;  $C = (L - 25)/25$ ;  $L$  is the actual channel length below Xihekou in km.

## 2.2 The average bed of main channel was declined

Fig. 3 shows the vertical section change of the estuary channel in the period between May 1986 and October 2005. From May 1986 to May 1996, because of the unfavorable water and sediment conditions, the river channel was silted and shrunk, the riverbed elevated almost 1 m in average and the vertical section was becoming slightly steep. Comparing the results in October 2005 with the operation of the Xiaolangdi Reservoir with October 1999 without the Xiaolangdi Reservoir, the riverbed was downcut dramatically, the average riverbed lowered almost 1.2 m; the vertical section was becoming gentle with 0.16‰ decrease in average. The average gradient dropped and the value was 1‰.

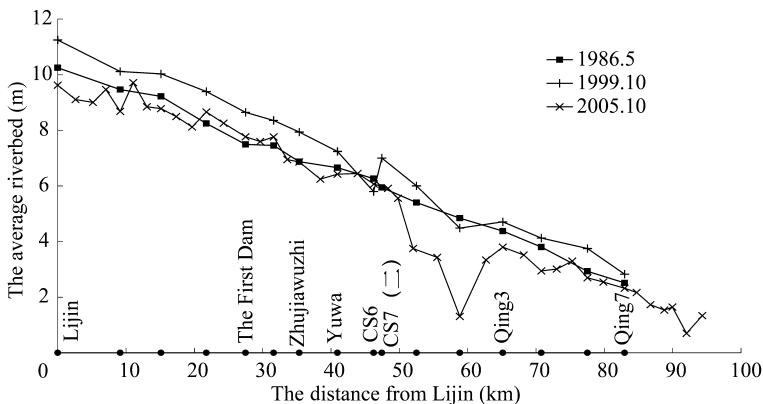


Fig. 3 The vertical section of the estuary channel

### 2.3 The flood discharging capacities of the main channels had been enlarged

Because of the clear water discharged by the Xiaolangdi Reservoir, which flushed the main channel instead of overflowing the floodplain, the flow area of the main channel had been increased. It can be seen from Fig. 4 that the flow area of the main channel that were above 2,000 m<sup>2</sup> mostly was big in 1985. The Qing1 is the biggest one with the area of 3,500 m<sup>2</sup> and the Qing7 is the smallest one of 1,640 m<sup>2</sup>. After the low flow series, the main channels were silted and shrunk. Before the operation of the Xiaolangdi Reservoir in 1999, the smallest flow area was Yuwa that was 820 m<sup>2</sup> and the flow area of the most of sections was no more than 1,500 m<sup>2</sup>. With the Xiaolangdi Reservoir, the flow area increased normally and most around 1,500 m<sup>2</sup>. The smallest section was Cs7 with 1,150 m<sup>2</sup>. Comparing to the data without the Xiaolangdi Reservoir, the smallest flow area increased by 330 m<sup>2</sup>, if estimated on account of 2.0 flow velocity, the bankfull discharge should increase 660 m<sup>3</sup>/s at least.

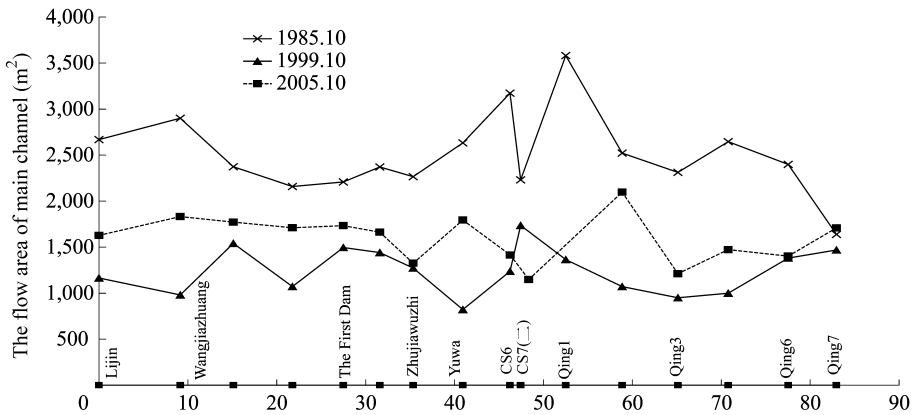


Fig. 4 The flow area change of the main channel

Lijin station bankfull discharge was 6,000 m<sup>3</sup>/s in 1985 and that of Shibagongli was 5,000 m<sup>3</sup>/s. After that, because of the consecutive low flow with less sediment, silt up of the estuary channel, the shrinking of the main channel, the declined bankfull discharge, Lijin station bankfull discharge reduced to around 3,200 m<sup>3</sup>/s and Shibagongli was 3,000 m<sup>3</sup>/s. After the operation of the Xiaolangdi Reservoir in 1999, due to its sediment control function, the less sediment concentration, the favorable water and sediment allocation, the scoured channel and the increased bankfull discharge, Lijin station bankfull discharge increased to around 3,700 m<sup>3</sup>/s in 2005. The enlarged discharge capacity of the main channel decreased the probability of overflow and dike breach.

### 3 No drying – up in the river channel was ensured

From 1986 to 1998, the LYR suffered consecutively drying – up. In the period of 1999 to 2005, except the high flow in 2003, the runoff was at low side. However, with the regulation of the Xiaolangdi Reservoir and the comprehensive measures applied, there was no drying – up in recent years. The notable regulation effect was in 2001. The runoff of Sanmenxia station in that year amounted to 13.79 billion m<sup>3</sup>, which was almost the same as the one in 1997, the driest year in history, which was 13.5 billion m<sup>3</sup>. The days when the average daily runoff was less than 10, 20, 50, 200, 500, 600, 800 m<sup>3</sup>/s were 9, 14, 22, 108, 235, 277 and 312 respectively. It was more 9, 14, 22, 6, 3, 11 and 9 days than those in 1997. The number of days in which the average daily

runoff was less than 100, 300 and 400 m<sup>3</sup>/s was 25, 127 and 176. It was 16, 33 and 31 days less than in 1977. In 1997, drying – up days was up to 226. In 2001 the runoff and low flow was almost the same as 1997, especially the low flow situation was even worse than 1997, no drying – up in the LYR channel was ensured by the sound operation of the Xiaolangdi Reservoir.

#### **4 The eco – environment in estuary was improved**

With 5 years' water and sediment regulation experiment and the operation of the Xiaolangdi Reservoir, it not only made the discharge capacity of the main channel somewhat recovered and the probability of overflow decreased, but also enlarged new silted area for the estuary to relax the seawater erosion there. The reality of no drying up of the Yellow River supplied the sufficient fresh water resources to the Yellow River delta and improved the eco – environment in this area effectively and returned the harmonious relationship between nature and human beings. The Yellow River bronze gudgeon which disappeared in 1980s is found in large group and the estuarine tapertail anchovy is also observed in the Yellow River estuary. Comparing to the situation without the operation of the Xiaolangdi Reservoir, the estuary wetland increased 5,000 ha; the bird species in the national estuary natural reserve has increased from 187 in 1990s to 283; there are 459 rare species of wild animal in the shell and wetland ecosystem protection zone, which has increased one time than that before unified water allocation. At the same time, the nutrient flux to the sea in no – flood season is increased, which has the positive influence to the offshore plankton, fish diversity and fisher production in the Yellow River estuary.

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# Study on the Theory and Application of Ecological Carrying Capacity Based on Health of Urban Water Ecosystem

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**Abstract:** The urban water ecosystem is the main and key factor of the urban ecosystem. By a comparative study between urban water system and human body health mechanism, the article defines Ecological Carrying Capacity on the basis of urban water health system, and then presents the quantitative model of urban water ecosystem carrying capacity (UWECC)—Pressure, based on which its calculating model is devised, including Natural Carrying Capacity (NCC) and social reviving carrying capacity. On the basis of urban water ecosystem indexes between carrying capacity and pressure, the health state of urban water ecosystem is described. Taking the city of Zhengzhou as an example, the author analyzes the comparative relationship between urban water ecosystem carrying capacity and pressure in the local areas in different periods before making a reasonable assessment on the health state of the city's water ecosystem. It is concluded that due to increasing the investment of environment construction and protection since 1995, the health state of the city's ecosystem has improved remarkably, the economy develops harmoniously with the urban water ecosystem.

**Key words:** urban water ecosystem health, ecological carrying capacity, assessment, Zhengzhou

## 1 Introduction

Carrying capacity, which derives from Nature Ecology, has changed from group carrying capacity, to resource carrying capacity (land carrying capacity and water resource carrying capacity), then to environmental carrying capacity and last to ecology carrying capacity. Being more systematic and complete and reasonable in ecological system assessment, compared with single factor carrying capacity, ecological carrying capacity has always been a focus of study for scholars from both in the country and abroad in recent years. The Canadian researcher William Rees, Wackernagel (1992, 1996) presents the theory of "ecological footprint" and applies it to Regional Ecology Security assessment. Chinese scholars Wang Zhonggen & Xia Jun (1999) employs the method of the gap between resource and human demand to measure regional ecological environmental carrying capacity. Gao Jixi (2001) divides ecology carrying capacity into resource carrying capacity, environmental carrying capacity and ecology flexibility capacity. He also adopts such indicators as carrying index, pressure index and carrying degree, etc. to describe the carrying situation of some specific ecosystem. Yu Danlin & Mao Hanying (2001, 2003) uses the carrying state point in the three dimension space consisted by human activities, resource and environment to describe Regional Ecology Carrying Capacity. The theories and methodologies discussed above have overcome the disadvantages of single factor carrying capacity, but the researches of ecology carrying capacity conducted from sustainable development and ecosystem health are not yet so commonly found. Yang Zhifeng & Sui Xin (2005) presents ecology carrying capacity on the basis of ecosystem health, which is divided into resource and environmental carrying capacity, flexibility and human activity potential. Moreover, an adequate assessment indicator system has been established to evaluate how the continued hydroelectric power construction influences ecology carrying capacity. However, in the field of urban water ecosystem, researches on probing ecology carrying capacity



from urban ecosystem perspective and the concerning evaluative investigations have not yet been reported. Comparing urban water ecosystem with human body health mechanism, this paper investigates the concept and connotation of carrying capacity and presents “Ecological Carrying Capacity – Pressure Quantitative Model” based on urban water ecosystem health by taking its development into consideration. Moreover, the health indexes of urban water ecosystem are also utilized to evaluate its health state. It is hoped that the present investigation could be of some guidance to the construction and management of urban water ecosystem.

## 2 A framework of Ecological Carrying Capacity on the basis of urban water ecosystem health

### 2.1 Analysis of urban water ecosystem health mechanism

The urban water ecosystem is the main part and key factor of urban ecosystem. Strictly speaking, it refers to a dynamic balanced system with a definite structure and function in a specific urban city, formulated by mutual interactions of the living biology in water and their environment by means of material circulation and energy flow. (Fang Ziyun, 2004) However, it is known that urban city is a highly humanized synthetic ecosystem in which the relationship between human community and water ecosystem tends to be more intimate than that in nature; therefore, the health state of urban water ecosystem is largely related to human factor. Owing to this, the urban water ecosystem health discussed in this paper also takes the welfare of human race into consideration besides the self – contained ecological structure of urban rivers and lakes. (Norris R H & Thoms M C, 1999) In terms of content, it includes not only the health of rivers & lakes water body, but also healthy operation of some infrastructure, such as urban waste water disposal equipments, urban water supply equipments and water drainage equipments, etc. Just as any organism, urban water ecosystem can maintain and regulate its own balance through self – metabolism in some sense. Therefore, it can be compared with a human body (see Table 1). It can realize its circulation process—source, supply, combine, drain and ensures its health by exploiting urban rivers and lakes water body, water supply equipments, waste water disposal equipments and water drainage equipments jointly.

**Table 1 Comparative analysis between urban water ecosystem and human body health mechanism**

Urban water ecosystem	Human body	Similarities
Urban rivers and lakes water body (water source)	Heart	Motivating source of maintaining ecological (physical) function (source)
Water supply equipments	Blood vessel	Supplying nutrients for maintaining operation of organism (supply)
Wetland, waster water disposal equipments	Kidney& liver	Clearing away harmful materials to ease consumption (combine)
Drainage equipments	evacuation system	Discharging waste (discharge)
Self eco – restoration	Self – immune	Maintaining health through self – regulating
Water conservancy investment	Extra medicine treatment	Restoring health via other assistant means

Similar to human health mechanism, through its own water resource restoring ability and environment clearing ability, the urban water ecosystem can solve some potential problems by itself brought about by human social and economical activities, such as large consumption of water resource, discharge of dirty and waster materials etc. The urban water ecosystem can keep healthy when the development speed of both the potential problems and the water ecosystem reaches a balance. Such state is also called self – balancing state. However, if the former exceeds the latter in speed in some degree, other means such as human technology (including waste water (rainwater) disposal or reusing, inter – basin water transfer, water ecological human restoration, etc. ) must be

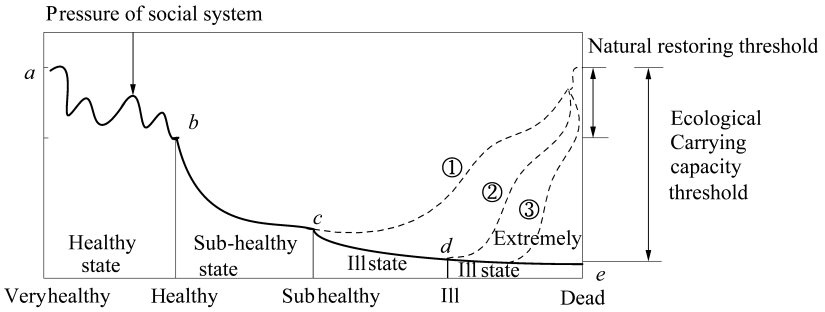
resorted to so that the whole system can keep in a healthy state, because only self-restoration of the ecosystem itself is far from adequate. These human-activity-featured economical ability (hydrological investment), human resource ability, technological ability, water-ecosystem construction ability and behavior ability guided by human awareness of ecology and environment protection can all be called developmental ability of human social and economical activities. Consequently, the health state of the water ecosystem is maintained by its intrinsic health-restoring ability and developmental ability of human social activities mutually. The former capacity is compared to the self-immune ability of human body, which can only be applied in a specific range to keep its health; the latter, being an assistant means, is compared to extra medicine treatment, which is considered to be an exterior motive of urban water ecosystem development.

## 2.2 Definition and connotation of ecological carrying capacity on the basis of urban water ecosystem health

Based on the above health mechanism of urban water ecosystem, Ecology Carrying Capacity can be defined as a potential ability for water ecosystem to maintain its service function (water supply, flood control, creature protection and scenery entertainment, etc.) and its own health in a specific social and economical condition. It is mainly manifested in the following two aspects: (a) natural restoring ability (flexibility) after the disappearance of pressures destroying its health state. (b) developmental ability of human social activities. That is, the human factors influencing Ecological Carrying Capacity. Thereby, the purpose of investigating Ecology Carrying Capacity on the basis of urban water ecosystem health lies in emphasizing the restraining and reactive relationship between human and urban water ecosystem in order to discuss the urban water ecosystem's combinative ability of maintaining its health under the condition of meeting the demand of human living standard and ecological environmental quality.

## 3 Ecological carrying capacity threshold theory of health evaluation of urban water ecosystem

Ecological Carrying Capacity on the basis of urban water ecosystem health is determined by the human requirements of living standard, demand for all kinds of service as well as city developing goal, and different levels of health state, i. e. the relative gradual dynamic features manifested in different health state range. Therefore, Ecology Carrying Capacity on the basis of urban water ecosystem health is not absolute and determinate, rather a threshold. In a certain limit, the system can restore health by its natural restoring ability, but if it is out of the limit, other measures by human beings must be exploited to restore the health of the system. Figure 1 shows the relationship among urban water ecosystem health, social and economical system pressure and Ecology Capacity Carrying of urban water ecosystem. When the pressure of social and economical system towards the urban water ecosystem is less than the system's automatic regulating threshold, the whole system will keep a dynamic balance ( $a-b$  in the figure), maintaining a healthy state. When the pressure is more than the system's automatic regulating threshold, the structure and function of the ecosystem will change, with the health state deteriorated. Thus the ecological quality of the system declines continuously and the water ecosystem is in a sub-health state ( $b-c$  in the figure). Now the health state can be regained through natural restoration. (restore curve ①). However, if no human measures are adopted to restore the ecosystem or the pressure of social and economical system becomes greater, the health state will continue to get worsened. Then the water ecosystem is in an ill state ( $c-d$  in the figure). At this moment, it is difficult to restore the health state only by natural restoration; instead, by human regulation be much possible to restore the water ecosystem (restore curve ②). If the health state exceeds point  $d$ , the whole system will degrade or die without any measures being taken. Then the system will be in an extremely ill state ( $d-e$  in the figure). Strong human restoring measures can still be applied to improving its health state (restore curve ③).



**Fig.1 Health state of urban water ecosystem and threshold of ecological carrying capacity**

#### 4 Ecological carrying capacity model on the basis of urban water ecosystem health and its evaluation

Based on the definition, connotation of Ecology Carrying Capacity of urban water ecosystem Health and Threshold Theory, Ecology Carrying Capacity and pressure of urban water ecosystem under a certain social and economical condition are calculated. Then by the health index of urban water ecosystem, the health state of the system are judged. Thus the degree of the sustainable development of urban water ecosystem is confirmed.

##### 4.1 Ecological carrying capacity calculating model on the basis of urban water ecosystem health

Based on the Ecology Carrying Capacity Theory Model, Ecology Carrying Capacity is subdivided into natural carrying capacity (NCC) and social reviving carrying capacity (SRCC), both of which are co-related by some relations by devising their respective calculating model.

(1) Natural carrying capacity calculating model in urban water ecosystem.

$$C_N = Ra_s^2 e^{b_s} \quad \text{with} \quad \begin{cases} R = k_1 A_w^2 \log_2^{A_w} P_w \\ a_s = k_2 Q_w / G \\ b_s = \frac{1}{n} \sum_{i=1}^n l_i K_i \end{cases} \quad (1)$$

In the above formula,  $C_N$  is the natural carrying capacity index.  $R$  is natural restoring index;  $\alpha_s$  is urban water resource supply index;  $b_s$  is urban water environmental carrying capacity index;  $A_w$  is the percentage of urban water area in the city's whole area.  $P_w$  is the flexible index of the system environment;  $Q_w$  is the amount of water resource supply;  $G$  is GDP (Gross Domestic Production);  $l_i$  is the proportion of waste materials in urban rivers and lakes water;  $K_i$  is the criterion of waste discharge in rivers;  $n$  symbolizes the types of wastes;  $k_1, k_2$  are used as constant to remove dimension, bearing no numerical value in calculation.

(2) Social Reviving Carrying Capacity Calculating Model in urban water ecosystem

$$C_S = mdEco \quad \text{with} \quad Eco = \frac{dG/G}{dP/P} \quad (2)$$

In the above formula,  $C_S$  refers to social reviving carrying capacity index;  $m$  is technology index (It can be shown by the percent of high-tech products production in the industry gross Production);  $d$  is human resource index (It can be expressed by the percent of labor force in the whole population);  $Eco$  is economical capacity index;  $dG/G$  is increase ratio of GDP;  $dP/P$  is population increase ratio.

(3) Ecological Carrying Capacity coupling Model on the basis of urban water ecosystem health

$$C_E = f(C_N, C_S) = rC_N e^{C_S} \quad (3)$$

In the above formula,  $C_E$  is Ecological Carrying Capacity on the basis of urban water ecosystem

health;  $r$  is the characteristic factor of urban water ecosystem development.

#### 4.2 Pressure calculating model on the basis of urban water ecology health

The pressure on the basis of UWEH is mainly expressed by the degree of water ecological system destroy caused by water resource consumption and water environment contamination, as the following formula shows:

$$P_E = a_u^2 e^{b_u} \text{ with } \left\{ \begin{array}{l} a_u = k_3 (P \bar{Q}_w + GQ_u) / G \\ b_u = \frac{1}{n} \sum_{i=1}^n \lambda_i (P \bar{Q}_i + GQ_{di}) \end{array} \right\} \quad (4)$$

In the above formula,  $P_E$  is pressure of social system;  $a_u$  is water resource consumption index;  $b_u$  is water environment contamination index;  $P$  is population;  $\bar{Q}_w$  is the amount of water resource consumption for average person;  $G$  is GDP;  $Q_u$  is ten thousand yuan GDP water resource consumption amount;  $\lambda$  is the proportion of waste materials in urban rivers and lakes water;  $\bar{Q}_i$  is amount of waste material  $i$  discharge in water for average person.  $Q_{di}$  is ten thousand yuan GDP waste discharge amount;  $k_3$  is used as constant to remove dimension.  $n$  is the types of water wastes.

#### 4.3 Urban water ecosystem health index

In order to evaluate the health state of urban water ecosystem, this paper devises an UWEHI with the numerical value from 0 to 1.0. Through the ratio between Ecology Carrying Capacity and pressure to react:

$$UWEHI = \frac{C_E}{P_S} \quad (5)$$

In the above formula,  $UWEHI$  is Urban Water Ecology Health Index, showing the health level of urban water ecosystem.

The relationship between UWEHI and health state is shown in the following Table 2.

**Table 2 Relationship between Urban Water Ecosystem Health Index and Its health state**

$UWEHI$	Health state	Symptom
0 ~ 0.25	Extremely ill state	Extremely weak in activity, destroyed structure, low restoring ability, loss of service function
0.25 ~ 0.5	Ill state	Inefficient activity, uncoordinated structure, weak in restoring ability and service function
0.5 ~ 0.75	Sub - healthy state	Average level in activity, structure, restoring ability and service function
0.75 ~ 1.0	Healthy state	very strong in activity, restoring ability and service function. Balanced structure

#### 5 Case study

Zhengzhou, which lies in the middle of China, is located in a semiarid and semi - humid area. In recent years, the city has strengthened its ecological environment construction and protection and proposes a definite developing goal—"Make Zhengzhou as National Region Centre". On the basis of the statistics of the city's development situation from 1999 to 2004, this paper applies "Pressure—Carrying Capacity Quantitative Model" based on Urban Water Ecology Health to calculate the comparative variation relationship between them, taking 1999 as the starting point.

## 5.1 Calculation of Ecological Carrying Capacity on the basis of Urban Water Ecosystem Health

Based on the collected statistics of Zhengzhou city's development, the variation tendency of UWECC can be calculated by Formula (3), as Fig.2 shows:

## 5.2 Calculation of Pressure of Urban Water Ecosystem

Using the above method, we can find out the variation tendency of pressure of Urban Water Ecosystem as Fig.2 shows.

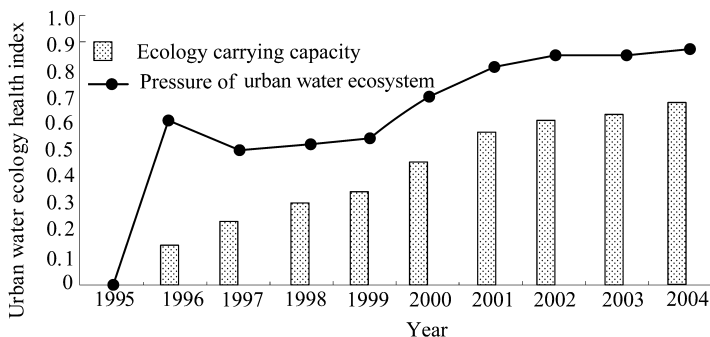


Fig.2 The relative variation of  $C_E$  and  $P_E$  of urban water ecosystem of Zhengzhou

## 5.3 Urban Water Ecosystem Health Index

Table 3 Calculating Results of urban water ecosystem health index of Zhengzhou and health state

Year	UWEHI	Health state
1995	—	—
1996	0.25	Ill state
1997	0.46	Ill state
1998	0.588	Sub - healthy state
1999	0.636	Sub - healthy state
2000	0.643	Sub - healthy state
2001	0.70	Sub - healthy state
2002	0.725	Sub - healthy state
2003	0.75	Sub - healthy state
2004	0.80	Healthy state

## 5.4 Result Analysis

It is concluded from the above calculating results that the water ecosystem carrying capacity has increased year after year and social pressure also tends to mount with occasional fluctuation from 1995 to 2004. UWEHI of the city also increases gradually and the relative health state changes from ill state to sub - healthy state and last to healthy state; especially after 1998, the city's ecosystem health state witnesses a remarkable improvement. It is mainly due to the massive measures taken to improve the water environment of some small cities' rivers and lakes (such as Dong Feng Canal, Xiong Er River, etc.) These measures have sped up the hydrological investment in the city's hydrology construction and outstanding achievements have been made. In 2003, the water ecosystem of the city was in a sub - healthy state, which is due to some of the city's projects of saving water and disposing wastes adequately. Meanwhile, with the gradual development of ecology hydrological project construction in eastern area of Zhengzhou, the water ecosystem health state has been greatly

improved. The researches show that the economical development and urban water ecosystem of the city has been developing harmoniously from 1995.

## 6 Conclusions

Unlike the previous discussions on water resource carrying capacity and water environment carrying capacity, the Ecological Carrying Capacity based on urban water ecosystem health is a highly compact notion with a harmonious coordination between human development and ecological protection.

There are two contributions in the present research. Firstly, this paper describes completely the potential ability of urban water ecosystem in maintaining its health state by foregrounding the interactive relations between human and urban water ecosystem by applying the standpoint of the System Theory. Secondly, it calculates the comparative relations between Urban Water Ecology Carrying Capacity and Pressure by means of “Pressure—Carrying Capacity Quantitative Model” based on Urban Water Ecology Health. Additionally, this paper also evaluates the city’s water ecosystem health state in different periods by means of UWEHI, providing a scientific foundation for the investment of ecology environment construction.

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# Thinking of Ecology on the Conservation and Restoration of the Loess Plateau's Vegetation

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**Abstract:** The problem of the Loess Plateau's eco-environment is caused by human activities after all. Under the pressure of a steady increase of population in the Loess Plateau, the eco-environment has been degraded so far. The crux of the matter is how to conserve and restore the vegetation of the Loess Plateau. This paper points out that the key strategies of the vegetation's restoration and conservation lie in the long-term population strategy, following the principle of conservation as the first priority and scientific method of restoration and conservation.

**Key words:** the Loess Plateau, eco-environment, vegetation, restoration and conservation

The Loess Plateau is famous not only because it is the largest area of loess in the world, but also is the cradle of Chinese nation. Its area is about 640,000 km<sup>2</sup>, covering 317 counties of 7 provinces. Now it is suffering the problem of the eco-environment which is caused by the long-term interaction of mankind and nature. The Loess Plateau is one of the regions subject to serious losses of soil and water and degeneration of eco-environment in the world. This greatly restricts the economic development of the Loess Plateau and North China, and threatens the eco-safety of East China. The key method of improving the eco-environment of the Loess Plateau and the silt of the Yellow River is to restore and protect the vegetation of the Loess Plateau. This paper studies the causes of the degeneration of the vegetation and discusses how to restore and protect it.

## 1 States of the Loess Plateau eco-environment

### 1.1 The vegetation on the Loess Plateau

The vegetation of the Loess Plateau is deforested seriously in the last a thousand years. With the population increasing to 36 million from several millions, the coverage of the vegetation was above 40% in the 6th century, and 30% in 17th century, and less than 6.0% in 1949 (Wang Guangzhi, 1995; Zhao Gang, 1996; Wang Naiang, et al, 2002; Jia Hongwei, 2004). For unfit method to restore the vegetation of the Loess Plateau lasting several decades, the coverage is still low after 1949. And the coverage is about 9.5% in 1990 (Dai Yali, Wen Tiemin, 2000). The coverage-ratio of the vegetation with the canopy density over 0.3 is less than 4.0% in 2000 (He Yongtao, et al., 2004).

The vegetation is closely related to climate. The coverage-ratio of the vegetation in the Loess Plateau was above 40% in the 6th century because the climate at that time was more wetness and had more rainfall than now (Zhu Kezheng, 1973). This is partly because of the wet climate, and partly because of the vegetation's eco-hydrology. In some way, the current arid climate in the Loess Plateau is partly because of the degeneration of vegetation. It may be the aftermath of deforesting.

### 1.2 Severe water soil losses on the Loess Plateau

The Loess Plateau is the region with the most serious water and soil losses in the world. The water and soil loss area is more than 71% of the Loess Plateau, about 454,000 km<sup>2</sup>. The area where the value of soil loss is more than 5,000 t/(km<sup>2</sup> · a) is 146,500 km<sup>2</sup>, more than 8,000

$t/(km^2 \cdot a)$  is 85,100  $km^2$ , more than 15,000  $t/(km^2 \cdot a)$  is 36,700  $km^2$ .

The water and soil losses there feature of the large area extensively affected, rapid speed of development, high value of erosive modulus and great quantity of sediment lost. There is about 2.1 billion t surface soil lost annually in this region of which, about 1.6 billion t sediment is transported into the Yellow River and about 100 million t flow into the Haihe River, and about 400 million t silt into reservoirs and ponds. The serious water and soil losses carry off too much fertile topsoil, so it causes not only the vegetation degraded and the eco – environment worse but also jammed the reservoirs and ponds.

### 1.3 Desertification and grassland degeneration

The desertification and the grassland degeneration become more and more worse in the Loess Plateau and are distributed widely and difficult to recover, though there is becoming better in somewhere. The desertification area is 2.05 million  $km^2$  in the Loess Plateau. It was reported by the China's Sustainable Development Report in 1999 that the desertification ratio of Shaanxi and Gansu provinces and Ningxia Autonomous Region are 15.96%, 50.62% and 75.98%, the grassland degeneration ratio are 58.55%, 45.17% and 97.37% respectively. The area of the Maowushu Desert was 1,836,000  $hm^2$  in the Inner Mongolia Autonomous Region in 1960s and was 3,825,000  $hm^2$  in 1990s. The spread ratio is 2.5% per year in this area. Now there is about 1,455,200  $hm^2$  sand land and moving sand are 200,000  $hm^2$ , and it is increasing by 3,900  $hm^2$  per year. In Shaanxi Province and Gansu Province, the sand farmland increased by 17,000  $hm^2$  and 9,000  $hm^2$ , 19.2% and 6.5% in 13 years (from 1986 to 1999). And in the 13 years, the sand grassland increased by 42,000  $hm^2$ , 18,000  $hm^2$ , 581,000  $hm^2$ , 4,213,000  $hm^2$  in Shaanxi Province, Gansu Province, Ningxia Autonomous Region and Inner Mongolia Autonomous Region, the rate of growth were 55.7%, 18.1%, 279.4% and 85.8%. The overgrazed is out of control in pastoral area.

In consequence of the cultivation and overgrazing, the grassland and forest have been degraded and the eco – environment has become worse in the Loess Plateau. The farmland was covered by sand in sand region because of sandstorm and dust devil. And the development and habitation of people in the Loess Plateau were imperiled seriously.

## 2 The main cause of damage the eco – environment of the loess plateau

The present eco – environment of the Loess Plateau is the consequence of the long – term interaction between human and nature. More people live in the Loess Plateau, worse the eco – environment becomes. The cultivation on a large scale is the most serious way to have damaged the eco – environment by the population increasing. The worsening of eco – environment in the contiguous areas of Shanxi, Shaanxi and Inner Mongolia is just because of several large scale cultivations in the period of the Qin – Han Dynasty, the Tang – Song Dynasty, the last of Qing Dynasty and the early of the PRC (Wang Guangzhi, 1995). Chen Kewei (1993) thought that the today's eco – environment are serious water and soil losses and hills barren of trees and innumerable valleys and gullies throughout the Loess Plateau. The causes are the misuse land after the Song Dynasty, especially after the Ming Dynasty and the Qing Dynasty. In those periods, the large scale cultivation had been taken place through mountains to plains. And it caused the serious water and soil losses and eco – environment became worse soon. It may bring about a striking effect in the degeneration eco – environment by the proper method. For example, the problems of black storm in the USA were under control in decades by the suitable land management. But the eco – environment was not turned better after more than 50 years comprehensive treatment. The Chinese scientific expedition team on water and soil losses and ecologic security investigated the Loess Plateau in 2006. The result was that the water and soil losses was still serious in most of areas but a few drainage basins after harnessing for over 50 years.

There are peculiar complexity and arduousness on the eco – environment of the Loess Plateau.



We may get half the result with twice the effort in recovering the eco – environment without considering all the causes of the fragile eco – environment. The main cause of the eco – environment of the Loess Plateau is the lasting increasing population. And the forest was destroyed and the weather became drier and drier under the pressure of the huge population.

## 2.1 The population of the Loess Plateau

The environmental problem is the problem of human in the final analysis. The austere challenge of the Loess Plateau environment is the problem of the lasting increasing population. The Fig. 1 is the change of the Loess Plateau's population in the last 500 years. With the society development, the population has been increasing in lately 500 years. Though it cut down one fourth in the late Qing Dynasty. The population has increased fast after the People's Republic of China was founded. The population increased 54.02 million from 1949 to 1990. And it is over 100 million in 2000. There are near 160 people per square kilometer in the Loess Plateau. It is as eight times as the bearing capacity of the arid and semiarid land. The increase population is huge per annum though our nation current population policy made the pace slow down. The pressure of population on the environment of the Loess Plateau will be stronger in future.

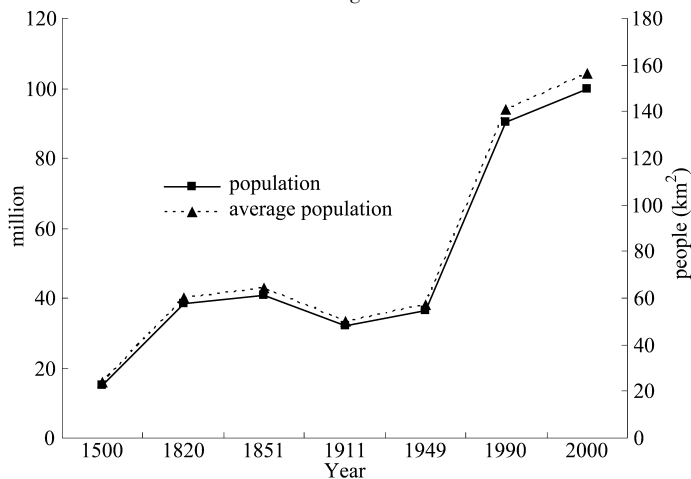
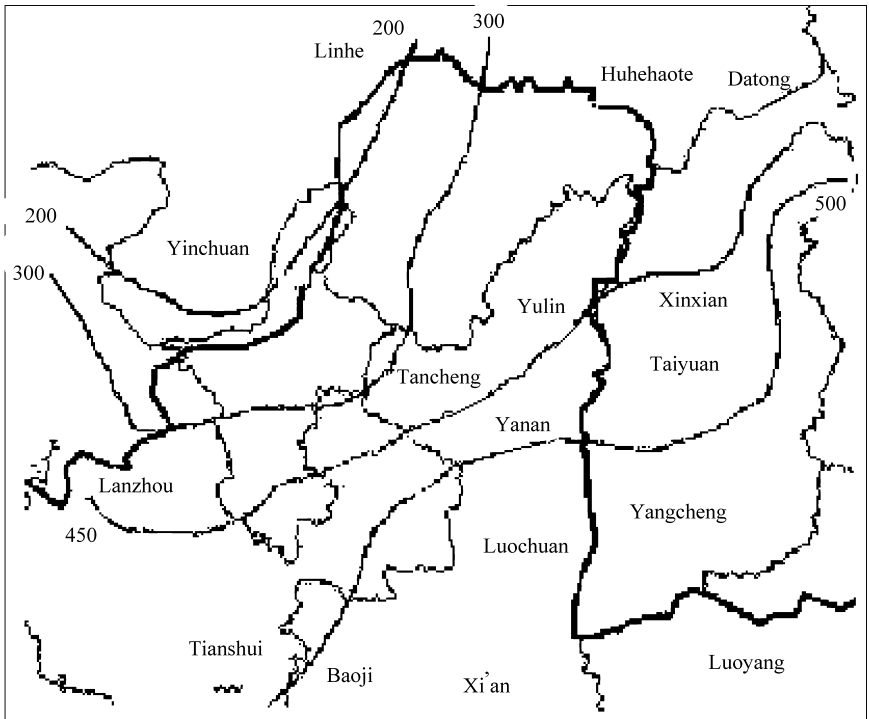


Fig. 1 The population changing of the Loess Plateau in 500 years

With the population lasting increasing and without inputting energy and foodstuff, it is inevitable to cultivate and deforest for living and development, from which a series problems such as soil and water losses and land desertification would be arisen. It faced the desertification again in the area of 28,500 hm<sup>2</sup> in Shaanxi Province where the affix and semi – affix sand was cultivated (BAI Zhili, et al, 2003).

## 2.2 The shortage of water resources

Water resources is the key factor of the vegetation restoration and eco – environment conservation in the Loess Plateau. The average annual rainfall is above 400mm in the most of area in the Loess Plateau (Fig. 2). And the rainfall is enough for forest growth (He Qingtang, 2001). But 70% of the total rainfall concentrates in the three months of July, August and September. And it makes so hardly to use the limited water resource that the rainfall can not be enough for forest growth.



**Fig. 2 Isolines of the average annual percipitation on the Loess Plaeau**

The shortage of water resources led up to exploit groundwater excessively. For example, the area of exploited groundwater in excess is up to 2,590 km<sup>2</sup> in Guanzhong district in Shaanxi Province. The groundwater level was stepped down from 1 ~ 3 m in 1950s to 13 m in 1990s in Minqin gounty in Ganshu Province. The groundwater level sharply dropping caused the more vegetation degenerated. It was reported in 1991 that the manmade oleaster forest in 1970s vegetated well is below one third and the natural shrub forest preserved below one third, too.

### **3 The strategy of the restoration and conservation vegetation on the Loess Plateau**

All Researchers thought the vegetation of the Loess Plateau can be recovered if taking the proper method. But they have different views on how to recover and which grade should be recovered on the vegetation. The most researchers thought the water resources decided the scale of the restoration and conservation of vegetation on the Loess Plateau and the restoration and conservation methods must be on the founded of the water resources (Yang Wenzhi, 2001; Shan Lun, 2001, Hu Jianzhong, Zhu Jinzhao, 2005; Shanguan Zhouping, 2005). We thought that the proper restoration and conservation methods must consider the press of the population and the water resources, and long-term and arduousness.

Being with the nation long run policy, we adduced the integration methods from the causes of the degeneration of the vegetation by the ecological theory and method. The eco-environment could be better and the vegetation might be recovered.

#### **3.1 The counter measure of the population on the Loess Plateau**

The environmental problem is the problem of human in the final analysis on the Loess Plateau.

The population statistics showed that the population was far more than 100 million. Although the bearing capacity of the Loess Plateau may be up to 60 persons per square kilometer for the advanced science and technology, the present population was far in excess of the bearing capacity. This showed that the population should reduce 60% for the sustainable development of this plateau. This target should be attained by the family planning policy and optimum resettlement. Established a new town by relocatees may transfer the agricultural population to non - agricultural population to relieve the press of the eco - environment. And it should make the family planning policy more efficient.

It is long - term to control the population density at 60 persons per square kilometer on the Loess Plateau. It is impossible to achieve this target without the long - term policy of the nation. If so, the restoration and conservation of vegetation were still a dream.

### 3.2 The countermeasure of the vegetation conservation on the Loess Plateau

Before the restoration of the present vegetation Loess Plateau, it is very important to conserve the Present vegetation; There are two ways to achieve this target; supplying enough energy and foodstuff.

Enough energy can be attained by making the most of the solar energy since there is enough solar energy on the Loess Plateau. And in somewhere, full utilization the biogas is a good strategy for the shortage of energy. It is possible to use the solar energy and biogas in place of the energy from the forest firewood. The results are not only making the eco - environment better but also conserving more vegetation on the Loess Plateau.

As for the foodstuff, we should change our idea. The shortage of foodstuff is more serious after the returning land for farming to forestry. It reduced the cultivated hillside about 2,320,700 hm<sup>2</sup>. For conservation and restoration of the vegetation, it should give up the idea of food self - support on the Loess Plateau. The problem of foodstuff may be solved by boosting output of main cropland and imputing food, otherwise, the food problem will be readily solved with the negative population growth.

### 3.3 The countermeasure of the vegetation restoration on the Loess Plateau

The shortage of water resources is one of the most difficult problems for restoring the vegetation on the Loess Plateau. If ignoring this, it would follow the same old disastrous road. For example, the conservation ratio of the manmade forest was below one seventeenth by the department of soil and water conservation over 50 years ( Bai Zhili, etal, 2003 ). It was reported that the total water resources was 55.494 billion m<sup>3</sup> ( Su Renqiong, 1996 ). But the minimum and suitable ecological water requirement of the forests in the Loess Plateau were approximately 26.249 billion m<sup>3</sup> and 42.134 billion m<sup>3</sup> and the water shortages were approximately 0.477 billion m<sup>3</sup> and 5.855 billion m<sup>3</sup> respectively.

It should solve the shortage of water resources in the Loess Plateau by the way of the following 3 steps. The first is the way of utilizing flood water as resources to make the most of the rainfall. The second is the way of the trans - basin water transfer to supply water. And the last is the way of the green water flow by restoring the vegetation to increasing the rainfall.

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## Discussion on Water Resources Protection and Management in the Yellow River Basin

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**Abstract:** In the Yellow River basin, water resources is lack, water pollution is serious, and the contradictory between the water resources supply and demand is more and more acute, the water resources protection in the Yellow River basin is facing up to many difficulties and pressures. The newly issued "Water Law" has brought the new opportunities and challenges for water resources protection in the Yellow River basin. Some measures should be taken to improve the present situation, such as establishing the integrated water resources management system with the rules and regulations and with the socialization of the region and basin; to improve the legal framework and establish a sound law system; to control the total volume of waste water based on the focus of the management of the water functional zones; to establish and improve a rapid response mechanism of the severe water pollution; to enforce the water quality monitoring mechanism and the technological innovation, to strengthen the basic research of the water resource protection; to build the information management system of the water resource protection; and to prevent the water pollution by the joint of the multi-sectors, which are the important prerequisite and tasks to do well in protecting the water resource in the Yellow River Basin.

**Key words:** Yellow River Basin, water resources protection, discussion, practice

Water Resources is absent in the Yellow River basin, and the contradiction between water supply and water demand becomes obvious, particularly since the 1990s, because of the increase of the river dry off, the severe water pollution, the deterioration of the ecological environment, and the increase of the water consumption from the rapid economy development in the basin. the Yellow River is enduring the tremendous pressures of the water supply. Because of the severe water pollution in the mainstream and tributaries, the volume of pollutants flowed into the Yellow River has been greatly beyond its environmental carrying capacity, which has led to the rapid deterioration of the aquatic environment and the worsening of the water quality. Therefore, the water resources protection in the Yellow River becomes more important.

### 1 The water resources situation in the Yellow River basin

#### 1.1 Water resources absence

The area of the Yellow River basin accounts for 8.3% of the national total area, but the quantity of the annual runoff only accounts for 2% of the national total volume. The water quantity for per capita in the basin is  $527 \text{ m}^3$ , which accounts for 22% of that of the nation's; The water quantity for per mu of croplands is  $294 \text{ m}^3$ , which only accounts for 16% of the nation's. The total quantity available of water resources in the basin is 2.4% of the annual mean gross amount of the water resources, the water quantity for per capita and per mu of croplands only accounts for 23% and 17% of the national average level respectively. After the 1970's, the actual annual runoff quantity in every station in Yellow River basically shows the decreasing tendency.

#### 1.2 The situation of the water resources exploitation and utilization

The Yellow River runoff utilization rate now stands at 53%, which is in a very high level at

home and abroad. There are 10,077 reservoirs and other type of water storage projects were built in Yellow River basin, of which there are 18 large reservoirs, their total storage capacity is 60.57 billion  $m^3$ . At present, the annual mean runoff which has been used to supply water in the supplying water areas of the Yellow River is 39.5 billion  $m^3$ . The problem of the excessive extraction of the groundwater is more serious in some city regions such as Xi'an, Taiyuan and some tributary basin.

Due to the short of water resources and the increase of the demand, the imbalance between the water supply and the water demand is the prominent problem faced by the Yellow River water resource management. In 1990s, the serious dry - off occurred in the lower reaches in the Yellow River. In 1997, the days and the length of the dry - off are 226 days and 704 km respectively, the days of the dry - off accounts for 62% of the whole year, and the length of dry - off accounts for 90% of the lower total reaches.

### 1.3 Basin ecology characteristics

In Yellow River basin, the ecological environment is frail and become worse, which was presented prominently by the soil erosion, the vegetation damage, the aquatic ecosystem evolution and the function decline. The headwater region of the Yellow River is the main source area of the basin water resources. At present, the problems of the ecology vegetation degeneration and the prairie desertification are increasingly serious. The water conservation capacity decreased significantly and there are many times dry - off in the headwater; the area of the soil erosion in the Loess Plateau has reached 454,000  $km^2$  in middle reach, which is the most serious ecosystem frail area of the soil erosion in the world, with the characteristic of the broad soil erosion area, large intensity, focus sand region, diverse type of the soil erosion, and the complex origin and so on. The harness is very difficult and the soil erosion is serious, which not only cause sediment problem, but also cause non - point pollution in Yellow River. Both are the biggest barrier in exploitation of water resource and ecological improvement. Dry - off is the main problem of the ecological influence in the lower reach and the estuary of the Yellow River.

## 2 Basin water quality and water pollution conditions

### 2.1 Basin water quality situation

In 2004, the 83 representative reaches from the mainstream, the first grade tributaries and some major second grade tributaries in the Yellow River Basin were chosen to evaluate the water quality status in the basin by using the single - factor method. The results showed there were 23,16,8,36 reaches in which water quality reached the class III, IV, V and beyond V of the China's surface water quality standard respectively, and accounted for 27.7%, 19.3%, 9.6% and 43.4% of the total evaluated cross - sections respectively. The percentage of each water quality class in the Yellow River was shown in Fig. 1.

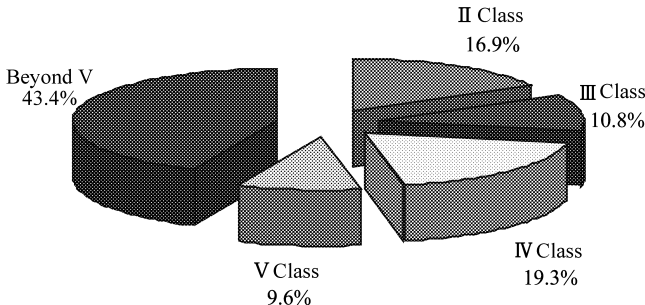


Fig. 1 Percentage of the water quality class in the Yellow River Basin

(1) In the mainstream of the Yellow River: In all there were 32 reaches evaluated, of which 34.4% of them reached the class III water in the mean whole year, 40.6% ,15.6% of them reached the class IV and V water respectively; 9.4% of them were beyond the class V water.

(2) In the major branches of Yellow River: In all there were 51 reaches evaluated, of which 23.5% of them reached the class III water in the mean whole year, both 5.9% of them reached the class IV , V water respectively; 64.7% of them were beyond the class V water.

(3) Water body in provincial boundary: there were 29 reaches evaluated, of which 27.5% of them reached the class III water in the mean whole year, 20.7% , 10.3% of them reached the class IV , V water respectively; 41.4% of them were beyond the class V water.

(4) In the key water functional zone: The 67 representative water quality reaches from 66 key water functional zones in the Yellow River basin were selected to assess and calculate the water quality status monthly by contrasting the water quality target of each water function zone. The ratio of the fulfilled the targets of the key water function zone in the Yellow River basin is 31.7% .

## 2.2 Point source pollution

At present, the produced sewage in Yellow River basin is directly discharged into the surface water body without any effective treatment. The total volume has accounted for above 20% of the actual runoff of many years' in Huayuankou station, which has seriously harmed the water quality restoration, and caused the serious water pollution. Statistics have indicated the waste water volume in the Yellow River basin is 4.265 billion tons in 2004. Among them, the sewage volume from city living is 1.049 billion tons, and the volume of the industrial waste water is 3.216 billion tons, which accounts for 19.9% and 73.5% of the total waste water.

## 2.3 Non – point pollution

Soil erosion is the most prominent non – point pollution sources in the Yellow River basin. After the sediment entering river course, the adsorbed heavy metal element, the organic colloid and the inorganic salts will affect the water quality maybe dueto the change of the pH value in the water body.

The agricultural production level in the Yellow River basin is not much too high, and the water volume used is big. The residual fertilizer, pesticide and so on in the soil of irrigation area has caused the water body pollution by drawing back water from farmland and runoff. The water pollution in the outlet of the drawn back water from the Ningmeng irrigation areas in the upstream is very serious. Actual value of the  $COD_{Cr}$ 、 $BOD_5$  reaches as high as 179 mg/L and 48.7 mg/L respectively in the drawn back water canal of the Wuliangshuai. Among the twelve investigated drawn water outlets of the agricultural irrigation, every year the quantities of the chemical oxygen demand, ammonia nitrogen, total nitrogen and total phosphorus input the Yellow River are 217,000 tons, 7,220 tons, 3,510 tons and 419 tons respectively, which is important non – point input area in the Yellow River.

## 2.4 Depositions endogenous pollution

In recent years, because the actual runoff in the Yellow River is small, the whole year discharged waste water along Yellow River is difficult to enter the water body with runoff in the dry season, which formed the channel deposit endogenous pollution with the Yellow River characteristic. Further it formed emergent pollution problem in the initial period of flood season.

For many years, the Yellow River basin and even China have carried out very few researches on non – point source and endogenous pollution. The total volume of the non – point pollution entered the river and its proportion accounted for the total pollution volume in the Yellow River basin have no comprehensive statistic and research. So they can be determined only after investigating and analyzing comprehensively the non – point source and the composition of the endogenous pollution.

### **3 The existing problems of the water resources protection in the Yellow River Basin**

#### **3.1 The laws and regulations system is imperfect, the administration by law is difficult**

In 2002, after the revised “Water Law” was issued and implemented, the laws and regulations system of water resources protection which adapts the new “Water Law” did not establish. But by now the administration by law exists some problems. It is very difficult to manage coordinately the enterprise’s pollution treatment, the environmental protection department’s pollution prevention and control, and the water conservancy department’s water resources protection in the basin level by law.

#### **3.2 The supervision and management of the water function zone is weak**

The water function management is the core of the basin water resources protection. Before the “Water Law” was revised, because the laws and regulations of water resources protection and the management system are not perfect, the government’s supervision function of water resources protection are not strong, and the surveillance safeguard system and technical method are backward, the main work of water resources protection only pause on the water quality monitoring business, and it is very difficult to create the effectiveness of law enforcement and the restraint mechanism on the action of discharging the waste water in the basin, which can not meet the request of the water function zone management.

#### **3.3 The responsibility of controlling the total pollutant volume does not put into effect**

At present, although the actual waste water emission has been far beyond the carrying capacity of the rivers at every province (municipality) in the Yellow River basin, objectives of the water functional and the river pollutant emissions controlled in every administrative area have not yet been determined. So far, the water resources management mechanism which the local government at all levels should be responsible for the water quality within their jurisdiction, and the water conservation assessment system of the heads of local administration at all levels are not perfect in the Yellow River Basin, and the water resources protection administrative responsibility does not put into effect.

#### **3.4 The supervision and management lacks the technological support**

The scientific and modern level of the water resources protection and management in Yellow River basin is relatively low; also all means of monitoring, information, evaluation, consultation are quite backward. Although in the early 1970’s, YRCC firstly set up some specialized institutes for water resources protection in China, and they have achieved many achievement’s as well. There is still a large gap in some fields such as administration by law, especially in the watershed sewage volume control and optimization technology, the ecological protection during the Yellow River management and development, the determination of the river ecological water demand, and the researches of the water resources protection regulations and the water resources management system in the basin.

#### **3.5 The ability construction of the water resources protection is insufficient**

The water resources protection is the social welfare undertakings of the government functions exercised, but it is incompatible with this is that there is no normal and smooth channels of funding in the past basin water resources protection, that the compensation mechanism of the basin water resources protection lacked, and that the infrastructure investment can not meet the needs of the functions carried out. In the end of the “Ninth Five – Year Plan” the investment of the water quality



monitoring infrastructure and the capacity – building have been improved in China, but it only meet the routine work, and is unable to use the modern hi – tech means of rapid mobility form of the supervision and management capacity to adapt to the need of the exercising of the water administrative functions by laws.

#### **4 The exploration and practice of the basin water resources protection**

##### **4.1 To improve the laws and regulations, and to establish and improve the law enforcement system**

It is the premise of the water resource protection that establishes and improves the regulations system and the law enforcement system for the water resources protection based on the basin unit. To meet the supervision and management need of the Yellow River Water resources protection, a corresponding law enforcement system of the water resources protection should be established, which will effectively superise and control the actions of protecting and managing water resources. The main components and the key points of the system are to perfect with the revised “water law” complementary system of regulations, to set up an administration law enforcement team, to establish an efficient operation mechanism, the routine work order and the convenient communication channels, to implement the combination of the basin unified management and the regional management, to achieve the social management of the basin water resources protection through the public management.

##### **4.2 To focus on the management of water function zone**

The water functional divisions is the water administration departments ( or watershed management agency) functions endowed by the new “water law”, and it is the law foundation of the management of the water administration department. The Yellow River water function zoning work has preliminarily been completed, and the results have been added into the “Chinese Water functional divisions (trial)”. At present, the “Chinese Water functional divisions (Tentative)” has been issued and implemented, but its legal effect is inadequate and it is difficult to intensify for the related management. From now on, the implementation of the water functional divisions will become the focus of the Yellow River basin water resources protection.

##### **4.3 To implement the system of controlling the total volume of the pollutants entered into the river**

To implement the system of controlling the total volume of pollutants entered into the rivers is the responsibility of the basin water resources protection organization endown by the new “water law”. Based on the water quality protection objective of the approval water functional division, the basin water resources protection agency will determine the carrying pollutant capacity of each water function zone, set up the total volume control index of the pollutants entered the river in each water function zone of the mainstream and tributaries in the Yellow River, and divide them into the annual volume based on the corresponding administration regions. Each province ( or municipality) will be responsible for implementing the controlling indexes of the total pollutant volume entered the Yellow River in their charged administration regions, and determine, divide and supervise the total pollutants volume in their charged regions based on these indexes.

##### **4.4 To establish the rapid response mechanism of the major water pollution incidents**

To deal with the unexpected water pollution events in the Yellow River, meanwhile to make it early found reported and treated, the Yellow River Conservancy Commission issued the “report method of the major water pollution accident in the Yellow River(trial)” and the “regulations of the rapid and investment and dealment with the major water pollution accident in the Yellow River”,

which has initially created the rapid response mechanism of the investment and dealment with the major water pollution accidents in the Yellow River. Practice has proven it is effective. The rapid response mechanism has played an important role in the rapid investment of the water pollution accidents such as the petroleum pollution accident in Lanzhou and the sudden abnormal water quality accident in Tongguan.

#### **4.5 To enforce the water quality monitoring mechanism and increase the technological innovation**

Water quality monitoring is the most important technology support of the water resources protection and the supervision management. With the new “Water Law” carrying out gradually, the supervision management will become the emphases of the water resources protection. While the important supervision managements are carried out, such as in the water functional zone, in the discharging outlets of the pollutants, in the permission of taking water, and in the implementation of controlling the total pollutants volume, the requests for the information of both the water quantity and quality will increase gradually. Therefore, it is necessary to optimize the station network, to use the advanced science and technology, so as to achieve the diversification of the monitoring method, to provide comprehensive, multifunctional water information services, to realize the overall new goals of the “optimized station network, the advanced technology, the perfected facilities, the rapid response, the multifunctional and administrative agency with good quality and high efficiency and so on”.

#### **4.6 To construct the information management system of the water resources protection**

The information management system of the water resources protection is a multi – directional, multi – time, three – dimensional description of the water quality information in Yellow River based on the integrated use of modern science and technology, which will gradually build a sustainable development system with the full support of the digital, information – based water Resources Protection. It ultimately realizes the monitoring technology modern, the data collection automatic, the information sharing, and the decision – making mangement intelligent.

#### **4.7 To implement the water eco – environment protection in the basin**

Ecological protection is the basic condition of the water resources protection in the water function protected areas and reserves of the basin in which they are the source areas of the important base – flow and the main carrying pollutant capacity in the middle and lower reaches of the Yellow River. Combining with the drinking – water protection and the reserves management in the Yellow River water function zones, the ecological protection of the Yellow River should be strengthened completely. Some key regional ecological protection should be carried out, and some ecological restoration demonstration projects should be built in some key waters. Based on the important goal of the basin water resoures protection, the water conservation forestry protection in the mainstream and the riverhead of the major tributaries, the soil erosion control and non – point pollution control in the middle district, and the restoration and protection of the major wetland in the basin should be enforced.

### **5 Conclusions**

The issues of Yellow River have been always paid attention to by the Chinese Party and the Government. In 1999, the General Secretary of the Chinese Party, Jiang Zemin, and other Chinese leaders have visited the Yellow River many times and given some important instructions, which call on us to study and resolve the major issues in the Yellow River from the strategic height of the entire national economy and the future long – term development. the former Minister of China Water Resources, Wang Shucheng, has proposed the new thought of the control water, which will change

from the traditional water conservancy to the modern water conservancy and to the sustainable water conservancy. We believe that the water pollution in the Yellow River will be eased and eventually be resolved under the care and support of the Party and government, and the works together of the water conservancy, the environmental protection departments, as well as the whole community. The Yellow River water resources development and utilization will soon embark on the road of sustained development of healthy track.

## Preliminary Discussion on the Health of River Ecosystem

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**Abstract:** With the worse and worse water quality and decreasing water quantity of the river, its constructure and function has been destroyed so that the sustainable development of regional economy has been restricted seriously. Therefore, how to recover and keep a healthy ecosystem of a river has become a very important strategy. A lot of theories and methods come out from the study of ecosystem of a river. This paper presents the concept and function of ecosystem of a river, discussing synthetically the main disturbant factors to the ecosystem of a river from mankind, and the indexes and evaluation methods of keeping a healthy ecosystem of a river etc.

**Key words:** sustainable development, ecosystem of a river, healthy evaluation, hydro – environment

With the development of regional economy and population, a great deal of pollutants from industry, agriculture and life are produced and flow into the river, so that the water quality is worsening and its constructure and function has been lost. Furthermore, because of the too quick water requirement of mankind, the water amount has been decreased in large scale and even zero – flow happens in some rivers. Thus, the self purification of the waterbody and the recovery capacity and the ecosystem of the river have decreased greatly. so as to restrict the sustainable development of regional economy. Therefore how to recover and keep a healthy ecosystem of a river has become a very important strategy for river basin management. The integrality of creatures and a healthy ecosystem for a river have been payed more and more attention. Based on the analysis and study, this paper try to summarize the theories and methods about how to keep a healthy ecosystem of a river.

### 1 Introduction to river ecosystem

The ecosystem of a river is a whole system with some constructs and functions, which includes 6 parts in general. The first is mineral which is within the substance circle. The second is organic compound related to creatures and non – creatures. The third is climate conditions such as temperature, illumination etc. The fourth is autotroph—producer. The fifth is macro – consumer. The last is mini – consumer, rotten trencherman or disintegrator. The former three parts are the non – creature ones, the late three parts are creature ones. The construct and function of creature environment is determined by non – creature environment which is the ecosystem factor most easy to be affected by mankind. The ecosystem of a river can be presented through the describe of function and structural character. The functional character focuses on the nutrient circle of nitrogen, phosphor, silicon and organic matter. And the structural character refers mainly to the component, number and distributing zone etc. which can be embodied by the indicators, such as the distribution and diversity of species etc.

There is a close relationship between the social development and ecosystem of a river. The serving function supported by the ecosystem of a river are as follows. The first is to supply water for drinking, industry and irrigation etc. Its value is determined by both water quantity and quality, which can be easily affected from outside. The second is to supply waterpower by the construction of dams. The third is to supply hydro – creatures who are the main body to supply service function. hydro – creatures have many zoology functions such as saving and circling of nourishments, keeping the diversity and evolution of creatures, absorbing, decomposing and indicating of pollutants, and supplying aquatic products etc. The last is to supply environmental benefit such as climate –

regulation, water – purification, lie fallow and entertainment, and navigation etc.

The river ecosystem has a function of self – regulation and self – repair. There is an up domino effect and down domino effect in the floodplain to coordinate the relations among creature community to sustain the stability and function of ecosystem of a river. As we know, during the slow evolution, adaptation each other has formed between creature community and its environment. In spite of the disturbance outside, the ecosystem can keep relatively stable by its self – control and self – repair. But when the disturbance exceeds a certain limitation, a positive or negative feedback far from the balanced point will come out to quicken the stability – lose of the ecosystem, which will result in complete breakdown and lose of service function of the ecosystem as a erupt manner.

## **2 The main disturbances from mankind to a river ecosystem**

Although there is a very long history for mankind to develop and utilize the river, the knowledge about the river is still quite indigent. The over – exploitation and use has damaged the structure and function to lead to zero – flow, nearly annihilation of species, decrease of life diversity and change of inhabitation environment etc. to restrict greatly the sustainable development of economy and zoology.

### **2.1 The impact from pollution to a river ecosystem**

The too quick increase of waste water and less disposal degree in China at present has led to severe river pollution and threatened the safety of water resources. According to the national investigation of water resources in 2000, the river length met with standard I of water quality only occupies 6.9% of total evaluation length of 284,978.7 km, the river length met with standard II of water quality occupies 37.5% of total evaluation length, the river length met with standard III of water quality occupies 37.5% of total evaluation length, and the river length met with standard IV ~ V of water quality occupies 33.9% of total evaluation length.

From the analysis and study for the materials of water quality in 44 main hydrological stations of the Yellow River basin since 1950, it can be seen that the kind and amount of main hydroniums present a slow increasing trend in the Yellow River river. The content of main hydroniums at many hydrological stations is nearly high up to the proportion of Yellow River water. The reasons of dense phenomenon of Yellow River water are as follows; The irrigated areas by Yellow River water are increasing gradually with an increasing Yellow River water – use amount, because most of the soil of irrigated areas is salt soil or salt – alkali soil, salt – wash process happens in the process of irrigation. Irrigated water will condenses after a great deal of evaporations. In addition, high mineralized groundwater intaked by parts of irrigated areas will result in the salt content of returned irrigated water is far higher than natural river water.

### **2.2 Effects from macro – water projects to a river ecosystem**

The characters of physics, chemistry and zoology of a river is the result that many factors take action synthetically. When a dam is built to form a man – made reservoir to store water across a river, a series of complicated chain reaction will come out in it. As we know, the river mouth is a place where salt water and fresh water meet. The environment here is complicated and changeable. Many important special characters of physics, chemistry and creatures make the river mouth become a ecosystem with special structure and divers functions. Because the environmental factors in river mouth vary excessively, the constructure of ecosystem here shows an obvious friability and sensitivity. even when there is only a light change outside, the succession direction may change.

More than 10 macro – reservoirs such as Xiaolangdi and Sanmenxia etc in the main channel have been constructed and have been playing vast function in the construction of local economy, zoology and environment. According to regulation principles of reservoirs, dams are used to cut flood peak during flood period, to increase discharge in dry season to promote the healthy ecosystem of a river. Whereas, zero – flow happen frequently in 1980s, and the lasting time and length of

zero – flow are increasing continuously. As a result, the development of economy, society and zoology has been affected greatly, which has aroused wide concern from the nation and abroad. The forming time of Yellow River estuary is not long with a low and plain topography. The seacoast here is unstable. Yellow River sediment and water are playing an important role to keep its deposit – rush balance. Combined with the complex dynamical mechanism, an abundant and special marsh and environment produces. In these years, affected by the Yellow River water and sediment, the sea line is changing from deposit forward to eroding back for this section, sea water inbreeds increasingly from decreasing ground water level, and soil here has Stalinized seriously, which has a large positive affection to the community structure and functions of plants in the marsh. Because the amount of water and sediment has been decreasing a great deal, the bait material resource of the Bohai sea will lose, the procreation and multiply of halobios will affected severely, a great lot of migration fish will vacillate to other places, so that the halobios chain will rupture and incapable reparative hurt will brought to the Bohai Sea ecosystem.

### **2.3 The biology diversity of river decreases**

There are complicated river ecosystems in China. Abundant of hydrophilic propagation species are supported by water. China is one of the countries whose fresh hydrophily species are the most abundant in the world of which many special types and categories possess especial economic and scientific values. At present, 92 kinds of fresh fishes are in face of menace. The reasons for the species to die out or be in severer danger are the shrink of water area, the fragmentation or segment of ecosystem, the inbreak of other species, the disappear of hygrophyte and eutrophication. In addition, the pollution of water environment is an important reason leading to the reduce of fish species.

## **3 The evaluation of the health of a river ecosystem**

### **3.1 The development of the health of a river ecosystem**

As we know the conception of the health of river ecosystem is developing continuously. Before 1950s, the understanding of the health of river ecosystem was emphasized particularly on the indicators of physical chemical aspects which were caused mainly by water pollution. From 1950s to 1990s, people began to realized the factors to affect the health of river ecosystem are so throng which includes great water projects, pollution, urbanism and so on, so the conception and evaluation method were put forward then. Epecially in European countries, USA and Austrilia etc, the function of zoology of a river was paying more and more atteniyon protecting river ecosystem in a large scale. From the point of view such as water quantity, water quality, habitat, species and so on, an evluation method of integrality of river ecosystem was put forward, which emphasized the resources function and zoology function at the same time. The idea of the health of river ecosystem has been developing from then on. After 1990s, the understand of the health of river ecosystem are becoming deeper and deeper. With the utilization of many kinds of means and indexes such as background information, river – bed data, sediment characters, vegetation types, river – bank erosion, the charcters of river – bank and soil use etc. , to evaluate the natural characters and quality and estimate the healthy degree of existing river ecosystem has come into use.

### **3.2 The conception of the health of a river ecosystem**

The conception of the health of river ecosystem is dynamic and developing whose connotation has a consanguineous correlation with the development of economics culture, science and technology. The purpose to evluate the health of river ecosystem is to confirm and identify the main factors who are affecting the river ecosystem in order to take relative measures to promote the health of river ecosystem. According to the main influences from mankind activity, it can be said that the health of river ecosystem is a state. In the state, the integrality of structure and function of river

ecosystem hasn't been changed by the impact from mankind to the hydrology water power process, physical chemistry factors and ecosystem etc. The basic contents include plentiful water quantity, benign water quality, natural current state, continuity of river ecosystem, diversity of species and well zoology service function etc.

### 3.3 The indexes to evaluate the health of a river ecosystem

The first condition to evaluate the health of river ecosystem is to ascertain appropriate evaluation indexes, but to ascertain reference aims is the key to ascertain evaluation indexes. In recent years, there are 4 kinds of reference aims below to evaluate the health of river ecosystem. The first reference aim is to be based on the ideal state in which the river ecosystem has recovered completely. Because of the disturbance of human activities and nature, it's too difficult to find a complete natural river ecosystem. Therefore, the first reference aim is too difficult to be applied in fact. The second reference aim is named as reference cross section method. Choose the less - disturbance cross section of a river from human activities and its environment characters such as hydrology, water quality, biology habitat and so on, then compare the environment characters of the studying river with them of the reference river to analyze the healthy degree of the river ecosystem. The third one is to take indexes of water quality as the main principles in spite of hydrology, zoology etc. The fourth one is named as integrated model of a river basin taking physics, chemistry and zoology status as its evaluation indexes to evaluate the healthy degree of the river ecosystem by physical chemistry evaluation, biology habitat evaluation, hydrological evaluation and biology estimate separately. In the evaluation systems of water body all over the world, the method used by USA is much famous. Through long term investigation of water quality, analyze water quality status of different ecology section and different rivers from water temperature, water quality, geology and ecology to accumulate a lot of experience and establish suitable evaluation methods. In Southern Africa, invertebrate, firm, river - bank vegetation and eco - environment are evaluation indicators. A great deal of techniques are applied in the evaluation of the health of river ecosystem such as sight ecology theory, remote sensing technique, instruct - trace, geography information systems and so on to promote the study headway of the evaluation of the health of river ecosystem.

### 3.4 Methods to evaluate the health of a river ecosystem

The evaluation process of the health of river ecosystem is to investigate firstly, to compare the investigation data with the appraisal standard or indexes secondly, and to analyze the healthy degree at last. There are two main methods named by pointer species method and index system method. The conjunction of combine microcosmic and macrocosmic is another method. Here in the complexity of the ecosystem and the response degree of different species to the outside disturbance, some pointer species such as phytoplankton and bottom - dwell invertebrate etc in the river ecosystem can be used to evaluate the healthy degree of the river ecosystem. This method is simple, but it has obvious bugs. Therefore different levels, times and spaces of species should be chosen when this method is applied. Hence index system method is developing subsequently. Both bionomics and toxicology method should be used in the evaluation of the health of river ecosystem 5 kinds of evaluation index systems have been established by now which are bionomics - toxicology method, epidemic method, ecosystem physic method, and combined method by economic index and ecological index, integrated method by different scales of information. Because all these methods above need much long - time supervise periods, some scholar has erected a forecasted model method to evaluate by dint of the mathematic model. Use the real biological constitution and possible vegetal species without jamming to set up a model. The healthy degree of the river ecosystem can be evaluated according to the specific values of forecasted values and measured ones.

It's the most important to think over the construct and function of the ecosystem itself. Then distinguish the threatened status of the ecosystem to tell from the furthest part. Thirdly study the important relationship between environment threat and the parameter change of ecology to put forward management countermeasures to keep the ecosystem healthy, which also should be

development direction of the evaluation of the health of of a river.

#### 4 Conclusions

A well method to evaluate the health of river ecosystem should be able to make complicated zoology phenomena simplified and quantitative, to present a simple explanation, and to combined with management aims scientifically. Based on the analysis of the impact to river ecosystem from mankind activities, choose some indexes such as hydrology, water power, physical chemistry and zoology of a river which can reflect the domino effects mentioned above to set up an adaptive evaluation index of the health of river ecosystem. By analyzing of the zoology domino effects of the river from mankind's activities, to take some relative measures can be able to reduce the zoology domino effects to realize the harmonious development between mankind and nature.

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# Effects of Soil and Water Conservation Measures on Hydrological Regime in Loess Plateau

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**Abstract:** Since the 1950s the hydrological regimes have been significantly influenced by anthropogenic factors such as large scale soil – water conservation measures in the Loess Plateau. While these measures have reduced soil erosion, they also result in noticeable changes in the stream flow regime. In this paper the changes of stream flow regime were evaluated in the Chabagou catchment. The results indicated that a noticeable inflexion of stream flow occurred in 1978 due to conservation measures. Average annual stream reduces by 30% compared with the period before 1978. Reductions in annual stream flow were associated with interannual and intraannual variability in stream flow. Stream flow in wet season appears to be the main factor responsible for the decrease in intraannual variability. In addition, the hydrological regime of the catchment was changed consistently with the up and down progress of sediment – trapping dams.

**Key words:** Loess Plateau, conservation, hydrological regime, flow duration curve

## 1 Introduction

The Loess Plateau is located in the Middle Reaches of the Yellow River and extends eight latitudes ( $35^{\circ}\text{N} \sim 41^{\circ}\text{N}$ ) and 13 longitudes ( $102^{\circ}\text{E} \sim 114^{\circ}\text{E}$ ), with total area of more than  $600,000\text{ km}^2$  (He, X. B., 2003). The average annual erosion rate ( $2,480\text{ t}/(\text{km}^2 \cdot \text{a})$ ) for the Yellow River Basin is the highest of any major river system worldwide (Ludwig and Probst, 1998, Shi and Shao, 2000), and the high sediment concentration in the Yellow River mainly originated from the soil erosion on the Loess Plateau. Every year about 1600,000,000 t sediments are taken into the lower Yellow River from the Loess Plateau. Since the 1960s, stream flow volume from the yellow river to the sea has decreased. The stream flow volume reduced to half in only several decades. More significantly, zero flow or periods without any flow at all occurred in the lower reach. Such dramatic changes in the hydrologic regime have profoundly impacted on economy, society, and environment. In the same period, a number of conservation measures were implemented in the catchments of the Loess Plateau to control soil erosion and maintain agricultural productivity, and the effect of soil – water conservation that reduced soil erosion appeared. So many people began to think about the relationship between soil – water conservation and hydrological regime (Xu, X. Y., 2000; Jing, K., 2002; Zhang, X. Z., 2005; Huang, M. B., 2003).

Through analyzing trends and changes of the stream flow, and comparing monthly flow duration curves for different periods in 1959 ~ 2000, this study evaluated the combined effects of soil – water conservation measures on hydrological regime in Chabagou catchment in the Loess Plateau. Such information can help catchment managers evaluate the effects of the soil – water conservation measures implemented in the last four decade, thus guiding to develop sustainable management plans in the region.

## 2 Study area and data

In order to detect a significant change in stream flow, catchment with a large percentage change in land use were required. Chabagou catchment is one stress region of soil – water conservation in the Loess Plateau.

The soil – water conservation measures in the catchments of Chabagou have been implemented

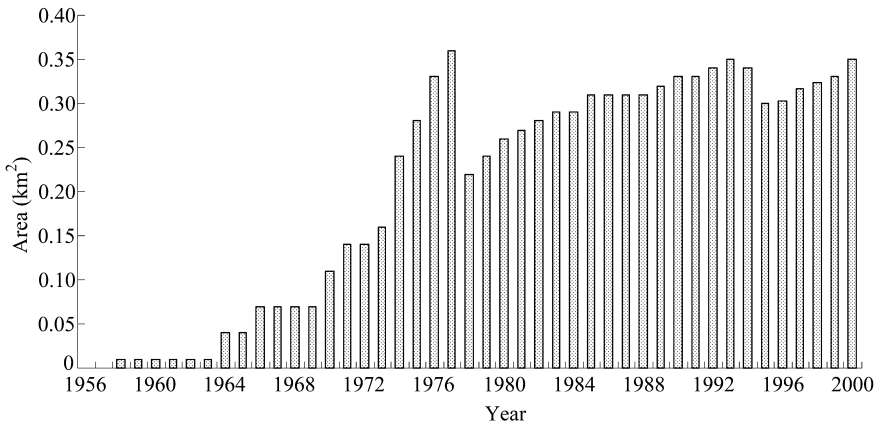
since 1956. The main conservation measures were afforesting, establishing pastures, and constructing terraces and sediment – trapping dams. The areas occupied by different soil – water conservation measures are listed in Table 1. It can be seen that the major expansion in soil – water conservation measures took place in the decade 1979 to 1989(Feng, G. A. , 2000) in the table.

**Table 1 Areas occupied by the different soil – water conservations measures**

Year	Terrace		Dams		Afforestation		Pasture		Total (km <sup>2</sup> )	RPC (%)
	km <sup>2</sup>	RA(%)	km <sup>2</sup>	RA(%)	km <sup>2</sup>	RA(%)	km <sup>2</sup>	RA(%)		
1956	0.00	0.00	0.00	0.00	0.27	100.00	0.00	0.00	0.27	0.14
1959	0.67	40.00	0.07	4.00	0.67	40.00	0.27	16.00	1.67	0.89
1969	3.60	39.71	0.47	5.15	1.00	11.03	4.00	44.12	9.07	4.85
1979	8.20	25.68	1.60	5.01	15.00	46.97	7.13	22.34	31.93	17.08
1989	19.20	21.97	2.13	2.44	52.33	59.88	13.73	15.71	87.40	46.74
1999	27.13	25.53	2.20	2.07	70.27	66.12	6.67	6.27	106.27	56.83
2000	27.47	24.80	2.33	2.11	73.47	66.35	7.47	6.74	110.73	59.22

**Note:** RA is the ratio of the area covered by single measure divided by the total area covered by all measures (%); RPC refers to the proportion of the total area covered by all measures in the area contributing to measurements at the gauging stations (%).

The soil – water conservation measures include engineering measures (i. e. , terraces and sediment – trapping dams) and vegetation control (i. e. , trees and pastures). Sediment – trapping dams is an important measures in engineering measures. They occupy much smaller areas but have more significant and immediately effects on stream flow. The development processes of sediment – trapping dams are up and down. Fig. 1 shows the areas occupied by sediment – trapping dams in Chabagou in period between 1956 and 2000.



**Fig. 1 Areas occupied by sediment – trapping dams**

### 3 Research methods

#### 3.1 Trend test

##### 3.1.1 Mann – Kendall test

Given a sample data set  $\{x_i, i = 1, 2, \dots, n\}$ , The Mann—Kendall (MK) statistical test (Sheng, Y., 2002; Zhang, Q., 2006) is based on the test statistic  $M$  defined as follows:

$$M = S/\sigma \quad (1)$$

where

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^n \text{sgn}(x_j - x_i) \quad (2)$$

and

$$\sigma_s^2 = \frac{n(n-1)(2n+5) - \sum_{i=1}^n t_i i(i-1)(2i+5)}{18} \quad (3)$$

where,  $x_i$  and  $x_j$  are the sequential data values;  $n$  is the length of the data set;  $\sigma_s$  is the variance,  $t_i$  is the number of ties of extent  $i$ . The function  $\text{sgn}(x)$  is defined as:

$$\text{sgn}(x) = \begin{cases} 1 & (x > 0) \\ 0 & (x = 0) \\ -1 & (x < 0) \end{cases} \quad (4)$$

Mann and Kendall have documented that when  $n \geq 8$ , the statistic  $S$  is approximately normally distributed with the mean of zero and the variance of  $\sigma_s$ . So the standardized  $M - K$  statistic  $M$  follows the standard normal distribution. The null hypothesis of no trend in the data is rejected at the  $\alpha$  significance level if  $|M| > u_{\alpha/2}$ , where  $u_{\alpha/2}$  is the  $\alpha/2$  quantile of the standard normal distribution. A positive  $M$  indicates an increasing trend in the time series, while a negative  $M$  indicates a decreasing trend.

##### 3.1.2 Spearman's Rank Correlation Test

Spearman's Rank Correlation (SR) test (Sheng, Y., 2002) is another non - parametric rank - order test. Given a sample data set  $\{x_t, t = 1, 2, \dots, n\}$ , the null hypothesis  $H_0$  of the SR test against trend tests is that all the  $x_t$  are independent and identically distributed; the alternative hypothesis is that  $x_t$  increases or decreases with  $t$ , that is trend exists. The test statistic is:

$$r = 1 - \frac{6 \sum_{i=1}^n d_i^2}{n^3 - n} \quad (5)$$

where,  $d_i = R_i - t$ ,  $R_i$  is the rank of the  $i$ th observation  $x_i$  in the sample of size  $n$ .

Under the null hypothesis, the distribution of  $r$  is asymptotically normal with the the mean of zero and the variance of  $V(r) = \frac{1}{n-1}$ . Using the following standardization,

$$T = \frac{r}{\sqrt{V(r)}} = \frac{6 \sum_{i=1}^n d_i^2 - n(n^2 - 1)}{n(n+1) \sqrt{n-1}} \quad (6)$$

the standardized statistic  $T$  follows the standard normal distribution  $T \sim N(0,1)$ . The null hypothesis of no trend in the data is rejected at the significance level if  $|T| > u_{\alpha/2}$ .

## 3.2 Jump point test

### 3.2.1 Moving t – test

The t – test assesses whether the means of two sub – samples are statistically different from each other. The formula for the t – test is a ratio expressed as

$$t = \frac{\bar{x}_1 - \bar{x}_2}{s \cdot \sqrt{\frac{1}{n_1} + \frac{1}{n_2}}} \quad (7)$$

and

$$s = \sqrt{\frac{n_1 s_1^2 + n_2 s_2^2}{n_1 + n_2 - 2}} \quad (8)$$

where,  $\bar{x}_i$ ,  $s$  and  $n_i$  are mean, standard variation and size of two independent samples ( $i = 1, 2$ ). And the degree of freedom in the t – test is  $n_1 + n_2 - 2$ .

Note that the number of change points and their locations are unknown. Instead of dividing the series into two sub – samples for a potential change point, we apply the t – test to only sub – series with a fixed length  $n$  before and after the potential change points. We call this method the moving t – test (Chen, J. ,2000). If  $|t| > t_{1-\alpha/2}$ , the point will be accepted as a change point at the significance level of  $\alpha$ . By moving the location of potential change point in the original series, we can detect all change points in the entire series.

In this study, we set the length of sub – samples to 10, while the significant level  $\alpha = 0.1$  with critical value is 1.734.

### 3.2.2 Orderly clustering method

In fact, in the orderly clustering method (Wang, G. Q. ,2001), to find the most potential change point of a sample set is to find the optimal division point through classifying the samples but not disturbing their order. So this method is similar to the optimal division algorithm.

Given a sample data set  $\{x_i, i = 1, 2, \dots, n\}$ , and there is only one change point  $\tau$  in this samples, So the sum of squares of two sub – samples before and after the change point can be expressed as follows:

$$V_\tau = \sum_{i=1}^{\tau} (x_i - \bar{x}_\tau)^2 \quad (9)$$

$$V_{n-\tau} = \sum_{i=\tau+1}^n (x_i - \bar{x}_{n-\tau})^2 \quad (10)$$

where,  $\bar{x}_\tau$  and  $\bar{x}_{n-\tau}$  are the means of sub – sample before and after the change point.

The total sum of squares is:

$$S_n(\tau) = V_\tau + V_{n-\tau} \quad (11)$$

The optimal division pointmeets:

$$S_n^* = \min \{ S_n(\tau) \} \quad (12)$$

so  $\tau_0$  is the most potential change point of the sample data set  $x_i$ .

## 3.3 Flow duration curve

A flow – duration curve (FDC) represents the relationship between the magnitude and frequency of stream flow. The magnitude is value of a discharge ( $Q$ ). The frequency is the percentile of stream flow versus exceedance probability  $p$ , where  $p$  is defined by:

$$p = 1 - p \{ Q_p \leq q \} \quad (13)$$

A flow duration curve (FDC) is a simple and powerful way of summarising the distribution of stream flow for a given catchment (Huang, G. R. ,2005). The FDC is widely used as a measure of

the flow regime as it provides an easy way of displaying the complete range of flow and it can also be used to assess changes in the flow regime following land use and climate change, by considering changes in percentile flows.

## 4 Results

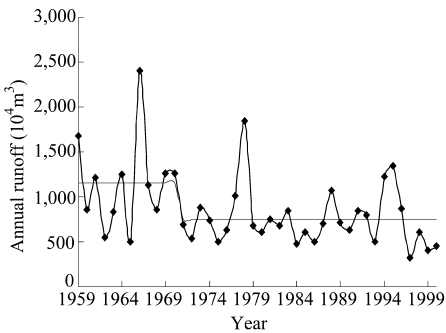
### 4.1 Annual stream flow trend and change point analysis

In this paper the MK test and SR test were used to identify trends in annual runoff and annual precipitation. Results showed significant downward trend in annual stream flow and no significant trend in annual precipitation (Table 2). Fig. 2 showed the process of annual runoff and annual precipitation.

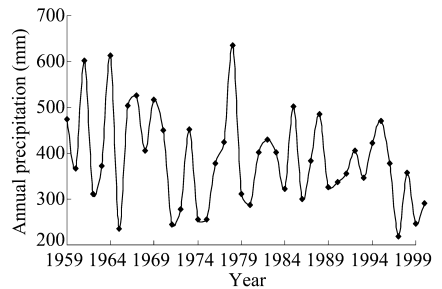
**Table 2 Results of trend test for annual runoff and precipitation**

Name	Annual runoff			Annual precipitation		
	1959 ~ 2000	1959 ~ 1977	1978 ~ 2000	1959 ~ 2000	1959 ~ 1977	1978 ~ 2000
Statistical value	-2.46	-0.78	-0.2	-1.57	0.41	0.23
MK test						
Significance level	**	ns	ns	ns	ns	ns
Statistical value	-2.59	-0.65	-0.5	-1.44	0.42	0.07
SR test						
Significance level	**	ns	ns	ns	ns	ns

**Note:**  $\alpha = 0.1$ , “+” means an increasing trend, while “-” means a decreasing trend. “\*\*\*” means the trend is extra significant at 10% level. “ns” means the trend is not significant.



(a) annual runoff

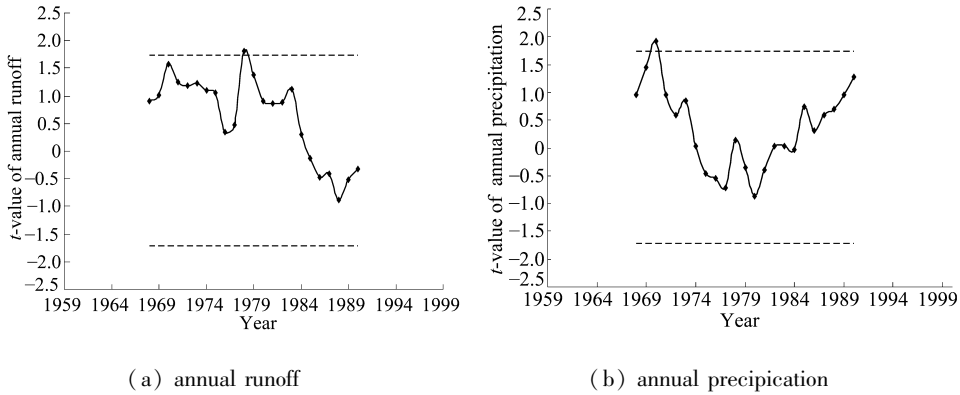


(b) annual precipitation

**Fig. 2 Changes of annual runoff and annual precipitation**

The moving t-test indicated that a change point occurred in 1978 in annual runoff, and a change point occurred in 1970 in annual precipitation while no significant trend during the period of record (Fig. 3). However, a significant change occurred in annual runoff in not only 1978 but also 1970 according to the orderly clustering method. So we suppose the change of runoff in 1970

attribute the to change of precipitation, and 1978 is the significant change point. To further validate above conclusion, trend analysis were applied to periods before and after 1978. The result showed there are no trend in annual runoff and precipitation in periods before and after 1978 (Table 2).



**Fig. 3 Results of change – point test with moving t – test for annual runoff and precipitation**

Sediment – trapping dams is an important measure in soil – water conservation measures. From Fig. 1, we can see that the areas occupied by sediment – trapping dams increased significantly. It came to climax in 1977, but decreased abruptly in 1978. The change point is consistent with the annual runoff. So stream flow records were divided into period “baseline” (1959 ~ 1977) and “treated” (1978 ~ 2000). Data from the baseline period (when there was no significant change in annual stream flow due to soil – water conservation measures) is used as the basis for comparison with the treated period (when significant change in annual stream flow occurred).

#### 4.2 Interannual variability in stream flow

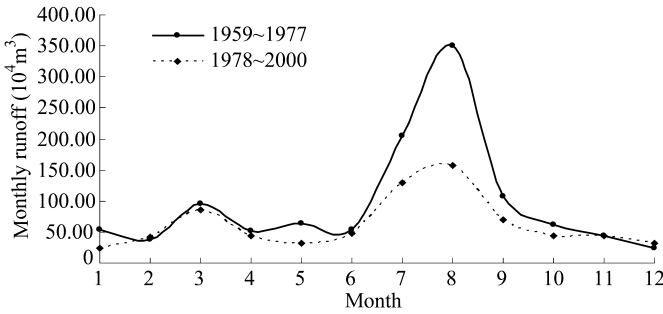
Chabagou catchment showed strong decreasing trends in annual stream flow. Table 3 showed annual stream flow reduced by 30% in treated period, the annual coefficient of variation in the period of 1978 ~ 2000 reduced by 18%.

**Table 3 Characteristics of annual stream – flow**

1959 ~ 2000		1959 ~ 1977		1978 ~ 2000	
$\bar{Q}(10^4 \text{ m}^3)$	$\bar{C}_v$	$\bar{Q}(10^4 \text{ m}^3)$	$\bar{C}_v$	$\bar{Q}(10^4 \text{ m}^3)$	$\bar{C}_v$
863.4	0.48	1,032.5	0.48	709.65	0.36

#### 4.3 Intraannual variability in stream flow

As shown in Fig. 4, there have been considerable changes in intraannual variability of stream flow. Average monthly stream flow reduced in almost all the month except in June, and stream flow during the wet season (July to October) reduced more evidently. Monthly coefficients of variation were calculated for the two respective periods (Table 4). After 1978, the coefficient of variation in monthly stream flow decreased. It mainly caused by the reduction of stream flow in wet season.



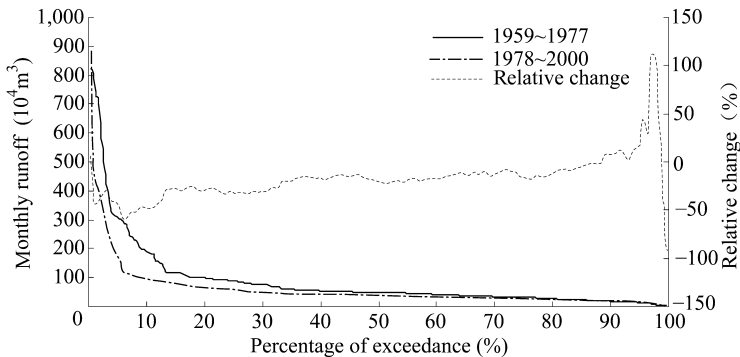
**Fig. 4** Changes of intra – annual variability of stream flow

**Table 4** Comparison of stream flow characteristics during the baseline and treated periods

Item	Chabagou	
	1956 ~ 1977	1978 ~ 2000
$Q_{50}$ ( $10^4 \text{ m}^3$ )	49.25	38.88
$C_v$	1.43	1.37
$Q_5$ ( $10^4 \text{ m}^3$ )	310.69	174.572
$Q_{95}$ ( $10^4 \text{ m}^3$ )	13.93	16.113

#### 4.4 Effects of soil – water conservation measures on daily flow duration curves

Fig. 5 shows the monthly flow duration curves for the baseline and treated periods. The relative reduction in monthly flow with the same percentile and their characteristic ratios are listed in Table 4. The reduction in flows was relatively constant, except for extremely high and low flows. In treated period, the monthly coefficients of variation reduced by 4.19%,  $Q_{50}$  (median flow) reduced by 21.06%,  $Q_5$  (high flow) reduced by 43.81%,  $Q_{95}$  (low flow) reduced by 15.67%.

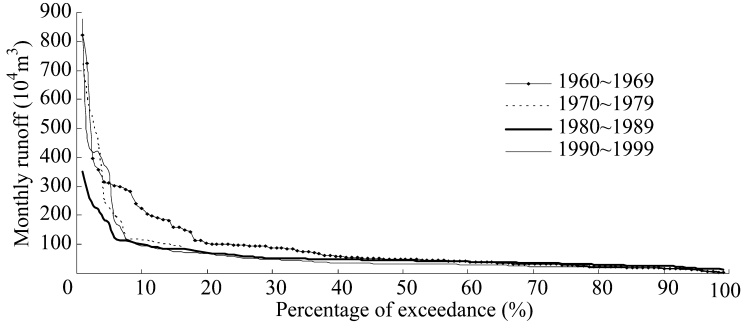


**Fig. 5** Changes of monthly flow duration curves (FDC) for the Chabagou catchment

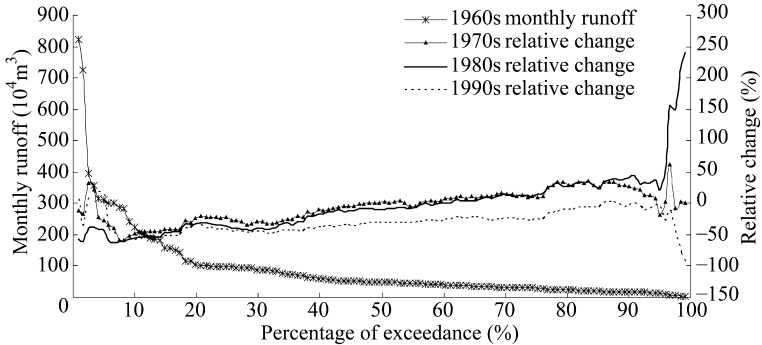
#### 4.5 Changes in daily flow duration curves over time

To further investigate the nature of the changes in the stream flow regime, monthly flow duration curves for each decade were constructed as shown in Fig. 6, and the relative change for each decade compared with the 1960s were constructed as shown in Fig. 7. FDC was disturbed most

significantly in the 1990s. There was little change in the FDC during the 1970s and 1980s in the catchment (see Fig. 6). The reductions in flows with the percentile from 10% to 90% were relatively constant, but extremely high and low flows changed dramatically. From the data in Table 5, we can see the monthly runoff decreased generally from 905,000 m<sup>3</sup> in the 1960s to 579,000 m<sup>3</sup> in the 1980s. In the 1990s, the monthly runoff increased to 62,800 m<sup>3</sup>.  $Q_5$  and  $Q_{95}$  are similar to those of the 1960s.



**Fig. 6** Changes in monthly flow duration curves over time for the Chabagou catchment



**Fig. 7** Relative changes of FDC compared with FDC of the 1960s

**Table 5** Characteristic flows during different periods

Period	1960s	1970s	1980s	1990s
Monthly runoff ( $10^4$ m <sup>3</sup> )	90.5	73.2	57.9	62.8
$Q_{50}$ ( $10^4$ m <sup>3</sup> )	48.86	49.25	44.06	33.57
$C_r$	1.34	1.41	0.87	1.74
$Q_5$ ( $10^4$ m <sup>3</sup> )	310.69	228.11	76.77	353.55
$Q_{95}$ ( $10^4$ m <sup>3</sup> )	13.93	11.25	16.87	13.39

## 5 Discussions and conclusions

Catchment in the Loess Plateau have been under the influence of human activities for centuries, with soil – water conservation measures accelerating and intensifying in the last four decade. While these measures have reduced soil erosion, they also result in noticeable changes in the stream flow regime. This paper investigated changes in stream flow regime of Chabagou



catchment for the period of 1956 to 2000.

According to above analysis, annual runoff showed significantly decreasing trend, and it was disturbed significantly by soil – water conservation in 1978. Some conclusion were obtained through comparing hydrological regimes in the baseline and treated periods showed: ① In treated period, average annual stream reduces by 30% , and interannual and intraannual variability in stream flow decreased. ② Average monthly stream flow reduced in almost all the month except in June, and stream flow during the wet season (July to October) reduced more evidently. Reduction of stream flow in wet season is the reason why intraannual variability in stream flow decreased. ③ The reduction in flows was relatively constant, except for extremely high and low flows, this phenomenon may be because sediment – trapping dams mainly regulate median flow and low flow.

In addition, this paper analyzed changes in daily flow duration curves over time. The hydrological regime of the catchment changed consistently with the up and down progresses of sediment – trapping dams. Before the 1970s a number of sediment – trapping dams were constructed. Construction of sediment – trapping dams came to climax in 1977, then in 1978, 80% of the dams were destroyed by flood (Feng, G. A. ,2000, Lu, Z. C. ,2006). So the hydrological regimes changed in 1978. In the 1980s the speed of construction dropped, and few sediment – trapping dams were built. So stream flow kept on reducing but there was little change in the FDC during the 1970s and 1980s. In the 1990s three – quarter sediment – trapping dams can not work. Then their effect on hydrological regimes decreased, and stream flow increased in the 1990s.

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# The Damage of Heap Sediment by Dredging from Irrigated Areas to Environment in the Lower Yellow River and its Prevention

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**Abstract:** For assuring irrigation district's natural function, the sediment aggraded in the canal and depositing pool must be dredged out timely. The sediment cleared away is usually stacked on both banks of canals, and after a considerable long period of time, artificial desert came into being, as a result, the environment around irrigation districts was destroyed, and the production and living of the people and economy development there were threatened. The paper introduces the austere actuality of stacking sediment. Summarizes modes of damage caused by the stacking sediment to eco - environment, thoroughly analyzes the degree and mechanism of stacking sediment, finally put forward the measures of prevention to offer technical support to harness the harm of stacking sediment in the irrigation districts along the Lower Yellow River.

**Key words:** the Lower Yellow River, irrigation district, harm of stacking sediment, environment, prevention and harnessing

## 1 Introduction

A lot of sediment is brought about while irrigating the farmland in the Lower Yellow River. As for the landform condition of the Lower Yellow River, whether people make use of essential theory of sediment movement or practical technology of abstraction, all of the sediment can not be transported to a far distance. Especially, the parts of coarser sediment mostly are concentrated at some key places, like settling basins and canals. For ensuring normal operation of the irrigation districts, dredging is needed periodically. The dredged sediment is stacking along the both sides of the canals. Day after day, the stacking sediment is piled up, forming a man - made desert. It destroys surrounding environment greatly, also influences people's work and life, even obstructs economy development. Firstly, the paper introduces the adverse actuality of stacking sediment. Secondly, summarizes main modes of stacking sediment harm. Thirdly, according as the keystone of sediment movement, the degree and mechanism of stacking sediment harm are analyzed extensively. Finally, the prevention measures of stacking sediment harm are put forward, offering technical support for harnessing stacking sediment in a scientific way.

## 2 Actuality and characteristic of stacking sediment in irrigation districts

A desilting basin is a main disposal means for sediment deposition in the irrigation district of the Lower Yellow River. For the need of depositing sediment, the desilting basins adopt the mode of digging instead of depositing mostly. The plane of desilting basin are fixed basically, sediment will be cleaned up when rising to a certain level, then the emptied storage will contain more sediment flowing into from canals, and that process is repeating again and again. The canals need to be dredged yearly in order to keep some ability in transporting both sediment and flow, and normal operation of the irrigation districts. All sediment dredged out from the desilting basins and canals is heaped up along both sides of them. Taking some typical irrigation districts as example, the abandoned sediment piled up on both sides of the canal in Sanyizhai irrigation district, with a length of 5 km, height of 1m to 6 m and width of 50 m to 40 m; the stacking sediment on both sides of the

settling basin of Weishan irrigation district of a area of 144 km<sup>2</sup>, piled high with a 533 hm<sup>2</sup> hathpace. Dredged sediment forms four sediment ridges of more than 70 m wide, nearly 7 m high and 400 hm<sup>2</sup> area on both sides of transporting sediment canal. That is commonly seen in the irrigation districts. A part of typical stacking areas of dredged sediment of irrigation districts is showed in Table 1. It can be seen from Table 1, for maintaining natural run of irrigation district, the stacking area of dredged sediment increases every year while dredging has been doing annually. Take the Weishan irrigation district as an example, because of water transporting to Tianjin in recent years, the disposal burden of sediment becomes heavy, dredged sediment occupies more and more land, expanding at a speed of 27 hm<sup>2</sup>/a. It is known from above analysis that the stacking area of dredged sediment is large and tends increase year after year.

**Table 1 The stacking area of dredged sediment of typical irrigation districts**

Irrigation districts	Xiezhai	Liuzhuang	Suge	Weishan	Panzhuang	Lijia'an	Bojili	Handun	Mazhazi
Stacking sediment area(hm <sup>2</sup> )	247	423	200	403	1,388	651	860	193	400
Increasing speed (hm <sup>2</sup> /a)	10.3	17.6	8.3	16.8	73.0	32.6	35.9	8.1	16.7

### 3 The mode of the stacking sediment harming environment

The stacking of dredged sediment of the irrigation districts of the Lower Yellow River insolate long, it makes the sediment containing no water and no mucous power. The sediment becomes a stacking of dispersive sediment grain that is easy to carry. A lot of coarse sediment has lower ability on keeping water and fertilizer, by reason of natural force, the coarse sediment will do harm to environment around irrigation district in course of movement. As the sediment is affected by different natural force, there are two modes of harming: one is loss of runoff and sediment, caused mainly by the natural force of raining. When it is raining, stacking sediment on both sides of a canal tends to be eroded by rain water. Stacking sediment follows rain from high position to high yield fertile land around canals, this turns the fertile land into desert, at the same time, it flows to canals, increasing quantity and difficulty of dredging to canal, and the expense of the dredging too. As an example, the most severely deposited strip canal at Bojili irrigation district is 22 km long, both sides of stacking sediment range between 120 m and 200 m in width and between 4~6 m in height, forming "a strip of desert". When it rains, sediment sheds everywhere, plant besides canal submerge in yellow mud. Day after day, soil on both sides of canal trends to desertification, its ability of keeping water and fertilizer decreases, and harvest reduces greatly. At the same time, plenty of sediment is taken to canal by rain inside of canal, which makes canal silt repeatedly. According to a rough estimate, the part of sediment takes 10% of yearly dredging in proportion to Bojili irrigation district, i. e. 100 thousand tons. This brings dredging expense high to 620 thousand yuan RMB. The other is sand blown by wind. Wind power brings on the movement of stacking sediment. Vertical distributing of wind speed follows index rule, stacking high of sediment delivers dispersive sediment grain to vertical high wind speed area directly. In dry and windy spring and winter, sand and dust weather of irrigation district is frequent, a mass of bedload along direction of wind advances to fertile land on both sides of canal, invades farmland and aggravates the land desertification. At the same time, suspended load moves transversely in a long distance, and its verticality reaches very high position, this not only destroys environment in several even hundreds kilometers bound of irrigating district, but also affects work and life of people seriously. The observation at the Bojili irrigation district shows that when it blows heavily, a great deal of bedload forms a layer of sand cloud like a moving blanket, moving jumpily to fertile land on both sides of canal. It is not long time, the farmland and crops put on a sandy coat, meanwhile, the suspended load flies in the sky, the sky turns to gloom, irrigation district is covered by a large curtain, a lot of fine sediment particles fly to field, village, and farm's houses. Even worse, it will lead to some disease spread.

## 4 Harm mechanism of stacking sediment in irrigation districts

### 4.1 Harm mechanism of water and sediment loss

The losing course of flow and sediment of stacking sediment in the irrigation districts can be divided into three stages. The first stage is erosion by spattering of rain water. A lot of raindrops come into being in the sky, with potential energy in quality and altitude, the potential energy, when falling, translates to kinetic energy gradually. At the moment of touching the surface of stacking sediment, previous potential energy exchanges all to kinetic energy which will do work to stacking sediment. This makes incompact stacking sediment grain spatter everywhere, the eroding process of rain water to the surface of stacking is finished, The American scholar Wischmeier and Smith have developed the experience expression of rainfall function:

$$E = 89I^2 + 210.2 \quad (1)$$

$E$  in this expression represents rainfall function,  $I$  is rainfall intensity.

The expression indicates that the bigger rainfall intensity is, the larger kinetic energy will be. In term of free – fall calculating, a raindrop of 6 mm in diameter descends while it has  $4.67 \times 10^4$  erg kinetic energy, the work can lift an object of weight 46.7 g to 1 cm high. So the bigger rainfall intensity is, the more prominent spattering erosion function is. The second stage is emergence and development of runoff erosion. While rainwater on stacking sediment surface is gather and sediment spattering on a large scale, erosion of stacking sediment runoff forms. According to current character on stacking sediment surface, runoff can be divided into piece flow on slope surface and thin section flow. The two flows are simultaneous, size of them lies mainly on mode of rainfall. Powerful rainstorm is easy to create piece flow on slope surface, but continued drizzle tends to form thin section flow. Different state of runoff produces varying mode of erosion too. Piece flow on slope surface erodes most surface of stacking sediment. Thin section flow makes sediment follow flow to field, depression, and drainage canal, etc. The third stage is gravity erosion. Movement mechanism of slope earth body is analyzed in literature, contrast relation between sliding force and skid resistance decided displacement of earth body:

$$K = \frac{\tau_f}{T} = \frac{N \cdot \tan\varphi + C \cdot A}{T} \quad (2)$$

where:  $N$  is a component of force of earth body gravity perpendicular to slope,  $\varphi$  is angle of internal friction,  $C$  is bond stress,  $A$  is contact area.

When  $K < 1$ , earth body will not be in a state of stabilization and take place displacement. With higher sediment stack, the slope angle  $\theta$  of sediment would become bigger, and the stability of stacking sediment body becomes poor. Following the development of rainwater erosion, the slope of sediment body becomes steeper, angle  $\theta$  is bigger, and the stability of stacking sediment body is worse. On the other hand, with the longes time of sediment piling, water content decreases gradually, bond stress also becomes small, even close to zero. By analyzing formula (2), it discloses that with the increase of stacking sediment in height and time, skid resistance trends towards small. When stacking sediment body  $\tau_f < T$ , stacking sediment collapses and hill – creeps by gravity. A side of massive sediment body falls to field around irrigation district, the other side of sediment body slides to canal and stack. Thus the loss course of flow and sediment of stacking sediment finishes generally. The loss course of flow and sediment also is the course of endangering environment around irrigation district. The degree of endangering environment lies mainly on the loss quantity of flow and sediment, it can be expressed by the following empirical relation expression:

$$W = k \frac{V^\alpha \cdot I^\beta}{d_{50}^\gamma} \quad (3)$$

in which,  $W$  is the loss quantity of flow and sediment,  $V$  is volume of stacking sediment,  $I$  is intensity of rainfall,  $d_{50}$  is median grain diameter of stacking sediment grain,  $k$  is coefficient,  $\alpha, \beta$ ,

$\gamma$  are indices.

Expression (3) shows the relation between the loss quantity of flow and sediment and main influence factor, and positive correlativity between the loss quantity of flow and sediment  $W$  and volume  $V$ , viz. the more stacking sediment is, the larger the loss of flow and sediment will be, vice versa. The loss quantity of flow and sediment of stacking sediment  $W$  and intensity of rainfall  $I$  present a positive correlativity, then the bigger  $I$  is, the larger  $W$  will become, vice versa. The relation between the loss quantity of flow and sediment of stacking sediment  $W$  and median grain diameter of stacking sediment grain presents a negative correlativity, namely, the coarser stacking sediment grain is, the larger  $W$  will be, vice versa. For a specific irrigation district of the Lower Yellow River, medium coefficient  $k$  and indices  $\alpha$ ,  $\beta$  and  $\gamma$  in the expression (3) can be rated by multiple regression analysis based on measured data. In addition to the above - mentioned influence of a few main factors, the surface of stacking sediment has not been protected by vegetation and renewable plants is also another important reason for heavy loss of flow and sediment.

#### 4.2 The harm mechanism of sand blown by wind

Analyzing the stacking sediment grain data of typical irrigation district in the Lower Yellow River shows that the proportion of sediment grain diameter ranging between 0.01 mm and 0.25 mm is about 90%. According to actual observation on the irrigation district in the lower Yellow River, dry sediment of grain diameter 0.25 mm starts movement at a speed of 4.5 m/s, namely 3 grade wind or so. Three - grade wind usually takes place in the Lower Yellow River. It shows that stacking sediment in irrigation district starts moving easily and comes into conveyance state. And people's production in this region is intensive, the machine vehicle runs to move frequently, this increases probability which sediment is disturbed and restarts in irrigation district.

Stacking sediment will roll to jump once they start. Sediment of grain diameter in 0.1 ~ 0.25 mm is easy to move by jump. It is a main bedload movement that stacking sediment advances by jump near ground. As a result, field is invaded directly and trends to desertification. Based on group grains average concept, Cao Wenhong etc. deduce a bedload rate expression of sand blown by wind according to physics mode of balance between jump resistance and sediment grain haulage:

$$g_b = \varphi \cdot \rho_s \cdot d \cdot (u_* - \lambda u_{*c}) \left( \frac{u_*}{u_{*c}} \right)^n \quad (4)$$

among this expressions,  $\varphi$  and  $\lambda$  are coefficients,  $\rho_s$  is sediment grain density,  $d$  is sediment grain diameter,  $u_*$  is the wind velocity of frictional resistance,  $u_{*c}$  is start the wind velocity of frictional resistance.

Bedload rate of sand blown by wind for three typical irrigation districts is calculated by using expression (4) in the paper, the result of calculation is showed in Fig. 1. When the wind reaches 2 grade, the bedload in three typical irrigation districts begins to move. When wind reaches 4 ~ 5 grade, the movement of bedload is quite active. Henceforth, the wind power is stronger, the increscent trend of bedload rate is more obvious.

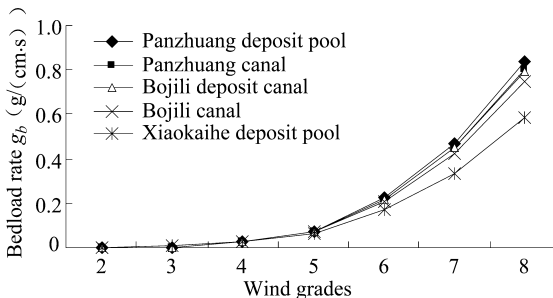


Fig. 1 The bedload rate in typical irrigation district of Lower Yellow River

Bagnold had brought the expression of sediment wave process of sand blown by wind:

$$c = \frac{g_b}{\gamma_s \Delta} \quad (5)$$

among the expression,  $g_b$  is bedload rate of single breadth of sand blown by wind,  $\gamma_s$  is unit weight of aggradation,  $\Delta$  is wave high of sediment. Formula (5) is used to compute the velocity of trenching on land of bedload. The result of calculation is showed in Table 2. It can be seen from Table 2 that, wind power is stronger, the velocity of trenching on land of bedload is more quick. According to actual state of irrigation district, if the wind power is strong enough, and blowing in some time, the velocity of trenching on land of bedload is very quick. For example, when wind power reached six grade in the Bojili irrigation district, the velocity of trenching on land is 6.3 cm/d. Sediment deposit canal is 22 m in length, full of stacking sediment, the stacking sediment will occupy 1,359 m<sup>2</sup> land in one day.

**Table 2 The velocity of trenching on land of bedload in typical irrigation district**

Irrigation district	Position	Velocity of trenching on land of bedload in different wind grade(mm/d)						
		2	3	4	5	6	7	8
Panzhuang	Canal	0.1	1.3	8.3	21.1	66.1	135.6	241.9
Bojili	Canal	0.2	1.5	8.6	20.9	63.4	128.1	226.4
Xiaokaihe	Deposit pool	0.4	1.8	8.0	18.1	51.7	101.7	176.5

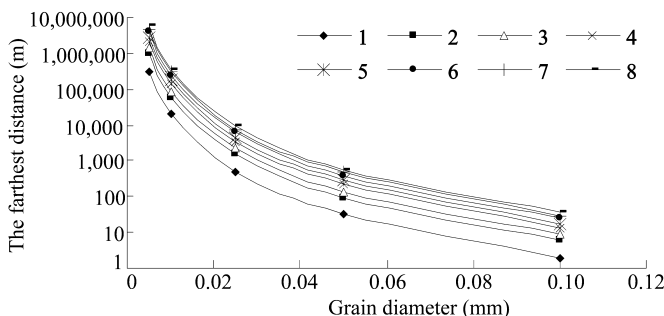
After stacking sediment starts moving, because the setting velocity of diameter less than 0.1 mm is less than upwards pulsating stress velocity per minute of airflow, suspending movement has more possibility. Stacking sediment of diameter less than 0.1 mm takes a large proportion in irrigation district of the Lower Yellow River, it is easy to suspend and float, its suspending distance, height and continuance in the air are close to its harm degree. Literature had put forward a formula about suspending distance of sediment, time and height:

$$L = \frac{40\varepsilon\mu^2 U}{\rho_s^2 g^2 D^4} \quad (6)$$

$$t = \frac{40\varepsilon\mu^2}{\rho_s^2 g^2 D^4} \quad (7)$$

$$H = \sqrt{2\varepsilon t} \quad (8)$$

In this formula,  $\mu$  is air viscosity coefficient,  $U$  is wind velocity,  $\rho_s$  is sediment density,  $\varepsilon$  is turbulence exchange coefficient. The Formulas (6) ~ (8) are used to calculates the farthest distance of different grain diameter sediment to suspending, the longest time of suspending in the air and the biggest height, the result of calculation is showed in Fig. 2 and Table 3. It can be seen from those, with suspending sediment grain size turning coarse to fine, the wind power is weakening, transporting distance of suspending sediment is shortening, suspend height is lowering, suspending time is becoming longer, and change scope is extending. Suspending sediment diameter less than 0.05 mm suspends long time in the air, suspending height by theoretical calculation is far beyond the height of surrounding villages, trees and buildings. Under the condition of definite wind power, the vertical scope covers the vertical space of people's life around irrigation districts, this also threatens people's activities and crop growth greatly.



**Fig. 2 The farthest distance of suspended sediment transported by different wind power in irrigation districts of lower Yellow River**

**Table 3 The longest time and biggest height of suspended load in irrigation district of Lower Yellow River**

Grain diameter of sediment (mm)	0.1	0.05	0.025	0.01	0.005
The longest time of suspending (s)	2	31	497	19,430	310,880
The biggest height of suspending (m)	6	25	100	623	2,493

## 5 Countermeasures against stacking sediment harm in irrigation districts

### 5.1 Diminishing the source of stacking sediment

To resolving stacking sediment harm to the irrigation districts, we should set about its source of stacking sediment and cut off it. Combining with practical condition of the irrigation districts, it is impossible from technical point of view that the source of stacking sediment is shut off. It can be done that quantity of sediment in depositing pools and canal is decreased by conceivable means. It is the essential approach that, sediment transported in a long distance by any means and enlarging the sediment proportion of input in the field.

The concrete measures can be divided into the engineering measures and the management measures. The start of the engineering measure is technique links, likes design of irrigation district and operation and so on, for gaining the biggest ability of transporting sediment of canals, it should pay attention to optimizing adjustment of hydraulic factors, such as section shape of canal, longitudinal slope and roughness. The usual engineering measures are as follows, optimizing design of canal section, canalization in technical innovation, contracting width of canal bottom, adjusting longitudinal slope of canal and so on. Familiar management measures are as follows, concentrative abstraction of big discharge, avoiding abstracting when sediment is much, decreasing abstraction in flood season, strengthening management to water demand, etc.

### 5.2 Rationally utilizing stacking sediment

The more amount of stacking sediment and longer time of piling would do the harm to environment, so the stacking sediment should be utilized rationally in a short time. A new thinking of water control is "human and water are harmonious". Keeping sediment processing as a burden is

an old conception, we must spurn it. We should erect the new idea that sediment is resource, we should change the harm to benefit, and maximizing benefit should be acquired during the sediment processing.

Returning stacking sediment to furrowing land is an effective mode of sediment processing. The Bojili irrigation district push the stacking sediment along canal evenly in 2005 year, it not only processed stacking sediment of many years, but also obtained lots of land. Economy crop was planted on this land, great economy benefit was gained. The stacking sediment can be exploited to be construction material, this method should be popularized energetically. Keeping the stacking sediment as raw material, many kinds of tile can be fired, this measure not only consumes the large amount of stacking sediment continually, but also a considerable economy benefit can be gained. A brickyard was built in Dongming County of Shandong Province, with productive capacity of 30,000 thousand pieces of bricks in one year, this consumed 70 thousand tons stacking sediment; its payoff is 900 thousand yuan RMB. Moreover, organizing local farmers to take the stacking sediment for homestead base or other, it dose not need a new soil stockpile, with advantages of lightening burden of the stacking sediment disposal, being convenient to people and saving land.

### 5.3 Biologic safeguard measures

If a biologic safeguard system is built, such as planning desilting basin and both sides of canal as a whole, arranging properly irrigation district surrounding, and planting around irrigation district, this will decrease the harm of stacking sediment to the lowest degree. Plants of irrigation districts can limit loss of flow and sediment. It shows that: ① The caudex and leaves of plants can head off raindrop, the direct beat to stacking sediment is weakened, the forming of exterior flow of stacking sediment was staved. ② The circumjacent soil of stacking sediment is safeguarded by the plant, because the plant can increase the roughness of ground and separate the flow of stacking sediment, at the same time, it can reduce the velocity of flow and accelerate aggradation of sediment. ③ Root system of plant can connect the surface soil and center soil to be one body, concretion force of soil increase. The prevention and cure of sand blown by wind function of plant are as follows, ① The plant enhanced the coarseness degree of bed surface, it improved jump – start wind speed, stacking sediment is difficult to enter into transporting estate. ② The caudex leaf of plant disturbed air current, it weakened wind speed of pressing close to stratum, it debased bedload rate of sand blown. ③ Biology shelter belt not only reduced wind speed of entering irrigate district greatly, but also hindered the movement of suspended load movement owing to its height of vertical direction. By analyzing above, we can know that virescence of irrigate district can effect a radical cure of harm of stacking sediment.

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# The Mode of Soil and Water Conservation Ecological Project in Jiehe Demonstration zone

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**Abstract:** The soil and water conservation ecological project demonstration zone of Jiehe watershed is the first large – scale soil and water conservation demonstration project in the Yellow River basin. The mode of soil and water conservation ecological engineering in the cities has basically been formed after 6 years' work, whose foundation is eco – environmental comprehensive control, whose keystone is developing economic forest fruit in big – scale as a main industry, whose characteristic is eco – tourism developing, which has come into been a mode and pattern for soil and water conservation ecological engineering of the Yellow River basin.

**Key words:** project of soil and water conservation ecological engineering demonstration zone, construction mode

The Jiehe river soil and water conservation ecological engineering project is the first large – scale demonstration zone in the Yellow River basin, which was ratified by Yellow River Conservancy Commission in October 1998. The increased soil erosion controlling area is as much as 520 km<sup>2</sup> by far. In the past 6 years, we have constructed terrace 13,751 hm<sup>2</sup>, planted forest 11,537 hm<sup>2</sup>, planted bush 3,116 hm<sup>2</sup>, planted economic forest fruit 16,592 hm<sup>2</sup>, grown artificial grass 2,674 hm<sup>2</sup>, closed off grass hillside 4,353 hm<sup>2</sup> for vegetation restoration, constructed 7 key dams of gully correction, 29 silt dams, built 3,124 check dam, built 717 gully head protecting projects, completed 4 central plant nursery, and completed 4 environmental forestation and beautification projects. A construction mode of soil and water conservation demonstration in city and suburbia area was successfully found, whose foundation is eco – environmental comprehensive control, whose keystone is developing economic forest fruit in big – scale as a main industry, whose characteristic is eco – tourism developing, which is a pattern of centralized investing to comprehensive controlling soil erosion in large – scale in the upper reaches and middle reaches of the Yellow River basin. The mode will powerfully impel the development of soil and water conservation in the Yellow River basin.

## 1 Basic circs of the demonstration zone

The Jiehe demonstration zone is situated at middle and upper reaches of the Weihe river, Tianshui City, Gansu Province, located at 34°20'19"N – 34°38'59"N, 105°07'50"E – 106°00'45' E. Jiehe is a first level branch at right bank of weihe river, on the south of which is Qinling mountain, on the north of which is the Jiehe river watershed, on the east of which is Mapaquan spring, in Beidao District, Tanshui City, on the west of which is Lixian County. The total area of the demonstration zone is 1,553 km<sup>2</sup>, including entire Jiehe river basin, whose area is 1,288 km<sup>2</sup>, and a part of Weihe river basin, whose area is 265 km<sup>2</sup>. The demonstration zone involves 16 towns and the street offices in 2 districts which are Qinzhou and Maiji of Tianshui City, and one county which is Gangu. Agricultural population in the demonstration zone was 260,000, and agricultural labor was 110,000. Average income per person was 960 yuan per year. The demonstration zone is situated at the transition belt of half moist – half arid climate in the warm temperate zone, where the mean annual precipitation is 566.8 mm. The type of soil is complex. With elevation declining there are drab soil, loess soil, dark loess soil, red soil, at different altitude. The demonstration

zone is at the transition belt of forest and grassland, where primarily vegetation is falling – leaf forest of warm temperate zone, as the forest prairie to the prairie zone of. Before the demonstration project built, the vegetation coverage of the demonstration zone was 20.69%. The mean annual modulus of soil erosion in the demonstration zone was 5,426 t/km<sup>2</sup>.

## 2 Constructing mode and technology

According to system engineering, eco – ecology and sustainable developing theory, the demonstration zone is regarded as a complete eco – ecology system, the natural resource protection and the economical development will be combined. The abstract of the demonstration zone is “one valley, two mountains, four sceneries, eight demonstration basins for highly effective government and development and thirty high – tech demonstration spot”. After comprehensive control of soil erosion, the erosion controlled area would be 980 km<sup>2</sup>, the governed rate would be above 80%, the land – use rate would reach 82.45%, the soil erosion would reduce above 70%; and farmer’s average income per person would be surpasses 1,500 yuan per year.

### 2.1 The mode of soil erosion comprehensive control

The Jiehe demonstration zone lies the third sub – region of loess plateau hilly – gully area, whose characteristic of landform is high hill and deep valley. The mainly erosion land in small watershed are slope – farming land, barren land and gully, where the soil erosion would be comprehensive controlled first, with the soil and water conservation measures in mountains, channels, fields, forests, roads, cellars and dams. The integrity and systematic characteristic of the watershed would be considered synthetically to position soil erosion comprehensive control measures. Every single measure would harmonious develop to bring whole protection effect into play.

#### 2.1.1 Terrace project

The terrace construction is the principal part of slope farming government in the Jiehe demonstration zone. According to the general plan of Jiehe demonstration zone, the ratifying paper of single measure design, the yearly scheme, the area region characteristic of different parts in the demonstration zone and local farmer’s housing conditions, one administrative village was a unit to choose the field, where soil texture was well, soil layer was thick, and slope gradient was below 20%, to construct terraced. The terrace which was in a uniform programming would be concentrated and concatenated in a certain scale, one slope after one slope and one range after one range. At the same time the assistant measures of terrace in mountains, channels, fields, forests and roads were synthetically considered. The terrace was constructed by machine and labor. If the contour line curved gently, the tending towards of terrace was along the contour line. On the other hand, if the contour line curved circuitously, the tending towards of terrace was along a certain beeline. The width of terrace was not smaller than 8 ~ 10 m. Both the height and the width of terrace field boundary ridge were not smaller than 30 cm, which could retain the rainstorm flood of 20 years recurrence period. Artificial grass such as alfalfa was grown on lots of terrace bank constructed by machine. According to the observing date by Tianshui station of Yellow River Conservancy Commission the terraced field can reduce 98% of the soil erosion, and store 92% of the runoff. At the same time, the production increase obviously, under the same condition, the production of terraced field was as much as 174.5% of the production in slope land. The increased production was 1,050 kg/hm<sup>2</sup>.

#### 2.1.2 Forest and pasture project

According to the local condition and the principle that suitable trees should be planted in suitable land, trees planted on sunny slope were mainly locust tree and seabuckthorn primarily, trees planted on shade slope were Chinese pine and oriental arborvitae. The main type of tree forest

was Chinese juniper, Chinese pine, locust tree, poplar tree, the oriental arborvitae and so on. The bush forest was usually in the steep slope and broken land. The main type of bush forest was seabuckthorn, caragana korshinskii. The artificial grass was grown in converted farmland, terrace banks and smooth and integrated barren slope. Alfalfa was grown in a great bound to increase surface vegetation coverage and forage for stockbreeding. The wild hillsides with better vegetation was delimited in a certain range and closed off to facilitate vegetation restoration. The type of forest was high tree forest shrub forest and tree – bush mixed forest. The preparing modes of forestation were square grid, level step, and scalelike pit. Simultaneously, the appropriate pattern was chosen according to the slope gradient. In gentle slope, where gradient was below  $15^\circ$ , the width of step was 1.6 ~ 1.7 m, the distance between one step and the next was 0.9 ~ 1.2 m. In a slope, where gradient was between  $15^\circ$  and  $20^\circ$ , the width of step was 1.4 ~ 1.5 m. The flood prevention standard was 20 years recurrence period storm. The technology of plastic film covering, bag covering, medicament of water conservation and medicament of prompting rooting were used to enhance survival rate in forestation. In forestation some method against drought were adopt, such as digging and transporting the sapling with an earth ball around the root, digging – transporting – planting the sapling in a continuous system, truncating pole, dipping slurry, planting deeply, irrigating, plastic film covering. The principles persisted in the entire forest grassland engineering were as follows: taking one small watershed as an unit, adjusting measures to local conditions, scientific programming, the forest belt constructed along the range and extending with the channel, planting trees by specialized teams, merging construction and management into one organic unit, enabling the survival rate of forestation to achieve above 90%.

### 2.1.3 Silt dam project

The channel is the place where runoff collects and washes most seriously. For one thing construction of terraced field, forest and grassland engineering play an importance pole in the soil erosion comprehensive control in demonstration zone. For another, 7 key dams of gully correction, 29 silt dams, 3,124 check dams, 717 gully head protecting projects were constructed in some necessary channels of important catchments, which can deposit 337,100 tons sediment, store 172,500  $\text{m}^3$  water annually, and play an importance pole in controlling basic point of erosion, preventing the extension of gully, retaining the runoff and sediment of a watershed.

## 2.2 The mode of developing economic forest fruit

According to the demand of people and the domestic development tendency of fruit variety, combined with the adjustment of the basin industrial structure in the watershed, the kind of economic forest fruit was reasonably designed, the amount of fruit trees was scientific decided. Notable, excellent, new and special fruit should be developed firstly. And, the belt of economical forest fruit should be constructed, to form industrial base with preponderant production and a certain scale. According to appropriate growing bound of each kind of economic forest fruit and the condition of demonstration zone, the development of economic forest fruit would be adjusting measures to local conditions. The construction of orchard should choose the field with good fertilizer and water condition, construct integrated and continuously. The orchard in the valley and hill where elevation is between 1,100 ~ 1,600 m is suitable to develop apples of notable, excellent, new and special type at first, where European – American big cherry, early crisp pear, late – maturing peach is suitable to develop reasonably. The place where elevation is between 1,400 ~ 1,800 m is suitable to develop apricot, pellicle walnut, ginkgo, eucommia ulmoides, Chinese prickly and so on. The wide level step whose width was 2 ~ 5 m was used to prepare for forestation. Economic forest fruit trees were plated in runoff collection ditch whose width was 1 m or the runoff collection pit (1 m  $\times$  1 m). The distance of each tree was 3 m  $\times$  4 m to 4 m  $\times$  5 m. The industries base of grape whose area was 666.7  $\text{hm}^2$ , the industries base of big cherry whose area was 666.7  $\text{hm}^2$  and the industries base of apple whose area was 666.7  $\text{hm}^2$  have been constructed in north range. The high quality fresh fruit forest belt of apple, peach, pear, big cherry, Australian blue apple has been

completed in south range.

### 2.3 The mode of developing eco – tourism

There are some landscapes in the Jiehe demonstration zone, such as Nanguo Temple which is one of the 8 places of sceneries in Qinzhou and the grave of Li Guang who lived in Han Dynasty and was called flying general. Because of abundant resource of land and tourism and the climate in the demonstration zone and preferential policy, more than 80 million Yuan social fund has been attracted to invest to explore the tourism resource. The eco – tourism demonstration zone of south range has been completed, the east of which is Qilidun of Yuquan town, the west of Lianting of Yuquan town, and whose total area is 700 hm<sup>2</sup>. The project of Nanguo Temple park, the Lver valley forest park, the flying general park, the Qingtupo precious botanical garden and whose nearby region have also been completed. The area was 555.56 hm<sup>2</sup>, where were 65 types of evergreen tree, flowers and economic forest fruit, such as deodar cedar, spruce, French phoenix tree, the oriental cherry blossom, Chinese ilex, magnolia, peony, rose, amorpha fruticosa, privet, gingkgo and China rose, and 2.75 million trees. All area suitable for forestry or grass was completely afforested, where the ecology landscape would be flower in the spring, shade in the summer, fruit in the fall and green in the winter, which enormously improved living environment and the image of the demonstration zone, promoted the city tourism's development.

## 3 The benefits of constructing mode

### 3.1 Ecological benefit

In the computation time, all of new erosion controlling measures in demonstration zone may reduce soil erosion as much as 482.78 million tons, the annual soil erosion total reduces from 4.34 million tons before the project was constructed to 1.47 million tons present, the soil erosion modulus reduces from 5,426 t/km<sup>2</sup> to 1,842 t/km<sup>2</sup>, reducing 66%. All new measures can retain surface runoff as much as 691.32 million m<sup>3</sup>. The annual runoff reduces from 80.25 million m<sup>3</sup> to 41.21 m<sup>3</sup>. The runoff modulus reduce from 87,300 m<sup>3</sup>/km<sup>2</sup> to 44,800 m<sup>3</sup>/km<sup>2</sup>, reducing 48.7%. Soil and water loss erosion has been controlled, every year the soil erosion reduces 2.87 million tons, the surface runoff reduces 39.04 m<sup>3</sup>, the harm of soil erosion and flood would be great lessen, and the ecological environment would be remarkably improved.

### 3.2 Economic benefit

In the past 6 years, the soil erosion controlled area in the demonstration zone increased is as 520 km<sup>2</sup>. The land – used rate increased from 70% before beginning of the project to 92%. The land productive enhanced from 4,400 yuan/hm<sup>2</sup> to 6,800 yuan/hm<sup>2</sup>. The grain yield increased 390,000 tons, the production of fruit was 3.98 million ton by monitoring and computation. In the computation time, the total economic income was 38.11 million yuan, the income each person increased 650 yuan.

### 3.3 Social benefit

The land – use configuration of agriculture, forest, pasture, barren land and others in the demonstration zone was adjusted from 49%, 14%, 1%, 12% and 24% to 29%, 47%, 8%, 0, and 15%, the land – use capability enhances from 64% to 85%. The total agricultural output value achieved 681.64 million Yuan, increased 33%. The soil erosion is under the efficient control, the land – use structure was adjustment reasonably. The ecological environment of tianshui city has

improved. The step of constructing well – off society in the demonstration zone was promoted. The external environment of sustainable development the demonstration zone has been better.

#### **4 Conclusions**

No matter in economy and in technology, the mode of soil and water conservation ecological engineering in Jiehe demonstration zone has achieved he anticipated goal through 6 years ' construction, whose characteristic is combination of engineering construction and eco – tourism, combination of soil and water conservation and countryside pillar industry construction, paying great attention to the economic benefit and the ecology benefit of the project, forming a new principle that development is prompted by government, at the same time, government is prompted by development. The project in Jiehe demonstration zone has provided a successful pathway for soil and water conservation in cities, set up an demonstration and a mode for soil and water conservation ecological engineering in the upper reaches and middle reaches of Yellow River basin. The mode of Jiehe demonstration zone is worth for profiting and promotion.

## Adaptability Analysis on Governing Measures in Coarse Silt Concentrated Areas of the Yellow River

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**Abstract:** This paper based on the full investigation and analysis of natural environment conditions and present governing measures of thick silt central source areas in the middle reach of Yellow River, analyses the natural environment condition, the social economy condition and the benefit of barring sand in the loess region, the soft rock area and covers the desert region which are three different governing areas, discusses the applicability of the governing measures of trench projects, for example the hydraulic – fill dam, sediment pool and so on, as well as the slope governing measures, such as terrace, forestry, grass and so on, proposes the different governing measures in different areas, has provided the scientific basis for the governing direction of the conservation of water and soil in this area.

**Key words:** thick silt central source area in middle reaches of Yellow River, conservation of water and soil; governing measure, benefits of barring sand

### 1 Introduction

The coarse silt concentrated areas in middle reaches of Yellow River locates in the middle reaches of Yellow River where particle size is more than 0.1 mm, the thick sediment runoff modulus is more than 1,400 t/(km<sup>2</sup> · a). These regions mainly distribute in Huangfuchuan, Qingshuichuan, Gushanchuan, Shimachuan, Kuyehe, Tuweihe, Jialuhe, Wulonghe, Wudinghe, Qingjianhe, Yanhe, etc. 11 river basins, the areas are 18,800 km<sup>2</sup>. At present approximately 500,000 hm<sup>2</sup> soil erosion can be governed initially, including basic farmland 100,000 hm<sup>2</sup>, artificial forest land lawn 397,100 hm<sup>2</sup>, 274 backbone projects of governing ditches, 13 sediment pools, 11,400 middle and small scale dams. According to geology, terrain landform, the soil, the vegetation, the climate and the economic society 6 kinds of index to reflect erosion situation, this region may be divided into the loess region, the soft rock area and covers the desert region three governing areas. In terms of present governing situation, This paper has done the preliminary analysis to the applicability of the governing projects and the biological measures, and provides the scientific basis for guiding governing silts in these areas.

### 1 Adaptability analysis of governing measures

Through reconnaissance and phantom material, key analysis different governing areas geologic structure, terrain landform, factors and so on trench characteristic and soil condition. In Geologic structure this paper mainly analyses trench bedrock stability and appearing degree of the trench projects ( For example sediment pool, governing trench backbone project and the silt arrester and so on ); In terrain landform it mainly analyses surface soil thickness, gully density, slope and so on, and discusses fixing suitable for building the ditching feasibility of a project and domatic project measure; In trench characteristic it mainly analyses trench gradient size, trench form of section and so on; The soil conditions are the main factors to affect ecological environment, therefore we carry on the diagnosis to the different soil condition, and define the locally floristic suitability.

According to investigation and society statistical data, have analysed rural economy income growth situation in different government areas in recent years, income structure composition, and

farmer demand and so on.

According to statistics test data of the measures of conservation of water and soil such as typical silt arrester, sediment pool, level terraced field, forestry grass and so on, analyse the quantity to block the putty (sand) with different governing measures, further discuss benefit and the function to block the putty.

## 2 Results and Discussion

### 2.1 Natural environment condition

#### 2.1.1 Loess regions

The loess region is the Yellow River thick central source discrimination cloth area biggest government area, its area is 14,634 km<sup>2</sup>. This area geologic structure is three repeat discipline stratum, many trench appearing has the sandstone, is advantageous for the gathering granulated substance, the stone material and so on; Ground cover loess thickness may amount to hundred meters, is lightly, the powder nature loam, loose porous, has the gradation good to build the dam earth material. This area majority of landforms are the loess hill shape, Liang Maozhuang the knoll gully, south the trench section plane many are V, the north many is U. This geology, the terrain, the landform, the trench characteristic and the soil condition are advantageous in the construction silt arrester and block the putty storehouse.

This area has constructs the level terraced field or plants the forest grass soil texture, the topographical condition, the former may take the level terraced field the suitable region, the latter besides the farming may take the forest grass the suitable region, and carries out the forest grass vegetation construction (see Table 1).

#### 2.1.2 The soft rock area

Northeast part the soft rock area is located, the area is 2,948 km<sup>2</sup>. This area has grown Huang Fuchuan, Kuyehe and so on the multi-sand coarse sand rivers, mainly divides into fills in the soft rock and the exposed the soft rock two kind of situations, in which fills in the soft rock area is the mesozoic era red tone clastic sedimentary rocks big area appearing, but the slope face cover caenozoic era loess, the red soil or the wind sandy soil region, has the ration the earth material, the granulated substance material and the stone material which constructs the dam to need, its host trench many is U, The average gradient 1.0% ~ 2.5%, the construction governs the ditch project the condition to have to surpass the loess region, but in the mineralization point distribution area, the downstream village and the Sichuan Taiwan place distribution crowded trench submergence loses too in a big way, the construction governs the ditch backbone project and sediment pool to be able to receive certain limit. After the consultation concerned expert, in does not remove in the investment possible situation, may in have the topographical condition area to construct the dam.

This area has builds the level terraced field the topographical condition, but nutrient content universal low, has limited the level terraced field scale development, in addition, this area vegetation degree of coverage is extremely low, the bare land area is big, needs to implement prohibits the protection, the promotion vegetation growth or the construction artificial vegetation (see Table 1).

**Table 1 The natural characteristic value in different governing areas**

Projects	Loess regions	Soft rock areas	Cover desert regions
The proportion of 5° ~ 25° slopes accounting for (%)	67.5	70.0	56.3
The proportion less than 35° slopes accounting for (%)	92	90	96
The average temperature per year (°C)	9 ~ 14	6 ~ 9	6 ~ 7



Continued to Table 1

Projects	Loess regions	Soft rock areas	Cover desert regions
The average annual rainfall (mm)	350 ~ 550	300	350 ~ 430
$\geq 10^{\circ}\text{C}$ of the accumulated temperature ( $^{\circ}\text{C}$ )	2,400 ~ 4,200	2,600 ~ 3,400	2,400 ~ 3,800
The areas of the low and middle covering degree (30% ~ 45%)	37.3	16.8	31.1
The areas of the low covering degree (10% ~ 30%)	40.2	23.5	23.1
The areas of bare lands (< 10%)	10.6	48.5	29.9
The density of gullies ( $\text{km}/\text{km}^2$ )	6.0 ~ 8.0	2.5 ~ 8.0	1.4 ~ 5.8
The erosion modulus (ten thousand $\text{t}/(\text{km}^2 \cdot \text{a})$ )	1 ~ 4	1.4	1 ~ 1.5

### 2.1.3 Covers the desert region

Covers the desert region is the area smallest region, is 1,221  $\text{km}^2$ . This area mainly distributes upstream Kuyehe the Ulanmulonhe river basin, excessive inundates the hillock slope region for the sandstorm landform to the loess landform, the soil parent material for under the Malan loess or the Cretaceous system the gravel nature residuals, the light chestnut soils gentle breeze sandy soil forms the flap to cover the ground. Compares with the loess region, its trench is broad, the trench gradient is small, the section plane is U. North this area terrain characteristic and the loess the area is extremely similar, conforms to the construction to govern the ditch backbone project and to block the putty storehouse the condition.

Covers the desert region ground line gradient most slow, has develops the terraced field, forestry grass the topographical condition, but this area mold landform important camp strength is the sandstorm, Covers in the sand bed rough region soil to include many sand, The soil calcareous tuberculosis, not easy to construct the ladder boundary ridge between fields ridge, the construction level terraced field quality very is not bad, the slope face is only suitable the development forest grass, but some covered the sand bed to be thin the loess deep region to be still suitable constructs the level terraced field (see Table 1).

## 2.2 Social economy condition

### 2.2.1 Loess region

Loess region population density averages 130 person/ $\text{km}^2$ . The average farming areas are only 0.18  $\text{hm}^2$ /person. The average basic farmlands only are 0.08  $\text{hm}^2$ /person, and dams are relatively less. The average outputs of 80% of uphill cultivated land are generally 750 kg per hectare, the disaster year even pellet not receives, but each hectare dam output may reach 5,000 kg, is slope farming output 4 ~ 6 times, the level terraced field area composition basic farmland 60% ~ 70%, the terraced field may increase production above 1.5 ~ 2 times compared to the slope cultivated land. Therefore, this area construction level terraced field and the silt arrester are advantageous in the enhancement the low - yielding land output, meets the populace basic life need. The loess region, in particular south the local construction level terraced field and the construction silt arrester has the good mass base.

This area construction sediment pool to be possible to retain the flood season unnecessary precipitation, realization rainfall runoff reasonable adjustment and effective use; Blocked the putty storehouse top of dam to become the connection trench both banks bridge, has facilitated the local populace, promoted the interflow of commodities and the market economy development, improved the agricultural production condition effectively. Therefore, people in these areas have high enthusiasm for constructing the silt arresters.

### 2.2.2 The soft rock area

The soft rock area population density is 20 ~ 33 person/km<sup>2</sup>, the population multi-accumulations middle and lower reaches the basin or the Sichuan Taiwan place relative many areas, average per person plants crops the 0.44 hm<sup>2</sup>/person, the terraced field and the irrigable land and so on the basic farmland only accounts for the cultivated area 5% ~ 6%, but the output low is not steady, arid year each hectare cultivated land grain yield only then about 350 kg; The natural pasture area occupies the land area above 70%, but passes through the long-term agriculture and reclamation and herds, the major part becomes the vegetation sparse to give up cultivation, the degenerated lawn and the difficult use corroded ditch land on slopes, the number of animals sustainable is only 0.5 sheepper unit; The animal husbandry management herds by the lawn primarily, adds it to lack the improved variety, the marketed proportion is not high, the economic efficiency is very bad. May rest on needs with possible to determine the implementation prohibits the protection, restores the ecology vegetation.

### 2.2.3 Covers desert region

This area population density 50 person/km<sup>2</sup>, the water resources is rich, surface cover wind sandy soil, but the soil texture bad, the use factor is low; This area quite part of areas are the coal field development zones, the population growth was in recent years quick, also concentrated nearby the mining area, the mining area enterprise production and the inhabitant lived the water consumption to grow quickly; This area has certain quantity agriculture place, the terraced field and the irrigable land and so on basic farmland proportion the soft rock area big somewhat, but the crop production also is does dryly by the land on slopes with the extensive cultivation primarily, the grain yield is not high; The vegetation resists drought the bush and the herb primarily; Not only the construction of silt arrester is the important measure of blocking silt in this area, but also is extremely important water source project.

## 2.3 Benefit analysis

### 2.3.1 Silt arresters to retain the benefit analysis

According to the investigation, this area water resources are relatively short, the dry season supply and demand contradiction is in particular more prominent, the construction silt arrester (is) can block effectively reduces the branch silt, adjusts the surface amount of runoff and the trench flood resources, raises the water resources use factor, to solves the native livestock potable water problem and the development agricultural production has the vital role.

(1) Silt arrester to all levels of trench inverse amplification factor high. According to the typical survey analysis, differently governs the area trench rank to be higher, the inverse amplification factor is higher, retains the effect to be more obvious. Third, four level of trench quantities are opposite in one, two level of trench quantity are few, the majority of government complete basin in three, four levels of trenches constructs governs the ditch backbone project, its upstream trench basic can governing. If the loess region fragrant-flowered garlic garden ditch belongs to the model lamination graduation to retain the silt arrester is a structure, its dam is the inverse amplification factor is 98.6%. Level trench inverse amplification factor is 49.0%, two level of trench inverse amplification factors is 66.7%, three level of trench inverse amplification factors is 97.4%, four level of trench inverse amplification factors is 98.6%.

(2) Silt arresters have remarkable benefit for sand traps. The quantity to blocked silts by Silt arrester generally account for above 60% of governing measures, close to normal distribution during construction stages. Namely, the dam group foundation initial period dam little blocks the putty quantity to be also few, the extension consolidated stage blocks the putty quantity to be biggest, the dam group construction later period gradually increases along with the siltation blocks the putty quantity to have the drop (to see Table 2). For example Huang Fuchuan, the Wudinghe River, Qingjianhe and the Yanhe silt arrester blocks the putty quantity to occupy the government measure to

block the putty quantity 66% – 84% , in which Qingjianhe reaches as high as 83.4% , various branches silt arrester blocks the putty quantity proportion for 70s to be higher than for the 80's ( to see Table 3 ). For example the Inner Mongolia accurate flag Sichuan palm ditch basin , up to the end of year 1999 , the construction governed the ditch backbone project 36 , silt arrester 110 , governing area 132km<sup>2</sup> , the storage capacity reaches 34,220,000 m<sup>3</sup> , has formed the more complete defensive system. On July 21, 1989, Sichuan palm ditch especially big rainstorm maximum point rainfall 141.2 mm , calculated biggest peak discharge 874 m<sup>3</sup>/s , produces Hong 12,337,000 m<sup>3</sup> , the silt arrester retains floodwater 5,932,200 m<sup>3</sup> , the reduction flood peak efficiency reaches 89.7% .

**Table 2 Benefit analysis of water storage and sand trap in the Yulin ditch basin**

Time (year)	Rainfall (mm)	Runoff yield (10,000 m <sup>3</sup> )	Storage (10,000 m <sup>3</sup> )	Sand yield (10,000 t)	Sand trap (10,000 t)	Storage efficiency (%)	Trap efficiency (%)
1957 ~ 1963	2,131.4	773.1	272.4	927.4	306.3	34.3	33.0
1964 ~ 1979	5,022.4	2,166.9	1,170.2	2,162.7	1,402.6	54.0	64.9
1980 ~ 1992	4,076.4	1,704.8	914.5	1,607.4	1,111.0	53.7	69.2
1957 ~ 1992	1,123.2	4,644.8	2,357.8	4,697.5	2,821.5	50.8	60.1

**Table 3 The situation analysis of silt arrester of typical branches**

Name of basins	Basin areas (km <sup>2</sup> )	Dam areas (10,000 hm <sup>2</sup> )	Trap efficiency in the 70s			Trap efficiency in the 80s		
			Governing measure (10,000 t)	Dam (10,000 t)	Percent of dam (%)	Governing measure (10,000 t)	Dam (10,000 t)	Percent of dam (%)
Wudinghe	30,260	472.8	9,466	7,231	74.6	5,226	2,201	42.1
Qingjianhe	4,080	110.55	1,862.7	1,560	83.7	1,305	867	66.4
Yanhe	7,687	101.25	931	614	66.0	1,530.5	852	55.7
Huang fuchuan	3,246	54.55	908.6	741	81.6	861.6	563	64.5

(3) Silt arresters have reduced the erosion effect. Silt arrester to be able to change the basin etching pattern obviously , specially raises the basis of erosion , the stable ditch slope , slows down or stops the ditch bed to undercut , the bank expansion and a ditch advance. According to the reckoning , 1957 ~ 1992 years , the Yulin ditch silt arrester reduces eclipses 864,000 t , the yearly average reduces eclipses 24,000 t , accounts for the corroded quantity 2.03% ; The basin trench raises 9 m equally , the ditch mouth basis of erosion raises 20 m ; Has not constructed under the dam trench cross section year to invade 0.05 m , under the most bumper year invades 4.5 m , but constructs under the dam trench cross section year to invade 0.015 m , the ditch slope undercuts reduces 69.4% , the ditch rate of progression reduces 58.7% .

### 2.3.2 Benefit analysis of sediment pool

Via carrying on the analysis to 13 sediment pools , its governing area is big , the storage capacity is big , and the interception sand quantity is big. Theoretically analyzes , the unit invests the cost to be low , blocks the putty effect to be remarkable , regardless of in the governing silt , stores and regulates the flood and safeguards the populace life and property security aspect , using the runoff , the increase water supply and the developed area economical aspect all has the extremely vital role.

For example sediment pool and the Kuyehe basin 116 governing trench backbone project to

loess region 10 compares, sediment average governing area  $123.7 \text{ km}^2$ , is equal in government trench backbone project 19 times, sediment average storage capacity  $41,024,000 \text{ m}^3$ , is equal in government trench backbone project 48 times;  $2,140,000 \text{ m}^3$  silts blocked by sediment pools are equal to 16 times of governing trench backbone projects. The explanation sediment pool is speeds up blocks reduces the silt the essential measure, must adopt the essential measure safeguard to block the putty storehouse security and to utilize continually.

### 2.3.3 Slope face measures retain the benefit analysis

The slope face government measure mainly has constructs the level terraced field, builds the woods, planter forage grass, guarantees the earth cultivation measure and so on, it retains the benefit analysis only to consider constructs the level terraced field, builds the woods, planter forage grass and so on three measures.<sup>[6]</sup>

(1) The benefit analysis of terraced fields. According to the research of blocking silts efficiency in the loess plateau areas, the level terraced fields increase rain water to infiltrate into underground water, reduce the amount of runoff, and reduce soil erosion, but the efficiency of blocking silts of the level terraced field relates to the their quality.

First, the different quality level terraced field retains the benefit difference under each kind of rainfall condition to be big. The research indicated that, the boundary ridge between fields high 25 cm level terraced field basically does not have the soil erosion, but the non – boundary ridge between fields terraced field can produce runoff 0.17 mm under the 9.5 mm rainfall, soil erosion modulus  $20.5 \text{ t/km}^2$ .

Next, the different quality terraced field retains the benefit difference in various flood seasons rainfall condition to be big, also is bigger along with the flood season rainfall increasing difference. When according to the experimental observation, the flood season rainfall is 231 mm, the terraced field, blocks sand benefit one kind respectively is 99.6% and 100%; Two kind respectively are 99% and 99.4%; Three kind respectively are 97.8% and 98.8%. When the flood season rainfall increases to 660 mm, the terraced field, blocks sand benefit one kind respectively is 54.2% and 58.0%; Two kind respectively are 36.9% and 39.9%; Three kind respectively are 19.6% and 21.2%.

(2) Forest grass retains the benefit analysis. Forest grass branches and leaves to be possible to intercept the rainfall, causes the ground to exempt the raindrop direct sputtering, reduces the ground amount of runoff and the wash load, thus reduction soil erosion modulus. According to the material analysis, the forest grass retains the benefit to gradually enhance along with the degree of coverage increase, after the degree of coverage reaches above 60% to be more obvious and to be stable, intercepts the sand the benefit to be remarkable especially, the degree of coverage 60% prevents the soil erosion for the plant the lower limit marginal value. Speaking of the region small basin government, the degree of coverage reaches when 70% ~ 85% can basically reduce the rainfall runoff one above the half, reduces the diameter miscarriage sand 80% ~ 98%.

## 3 Conclusions and suggestion

### 3.1 Conclusions

#### 3.1.1 Regions have the good dam storehouse construction topographical condition

The loess region fills in deeply, the stratum structure quite is stable, majority of drain off, the ditch sincere bedrock, the run – off ditch corrosion produces the sand proportion to be high, has the construction trench dam is and sediment pool the condition, the north area government trench backbone project and the middle and small scale dam disposition proportion is opposite in the south area must be high; Covers the desert region to cover the safranin mound of earth mausoleum landform corrosion to produce the sand to be most intense, its trench section plane many is U, suits constructs various types silt arrester and sediment pool, but the adaptation degree is lower than the loess region, the construction silt arrester is the condition relative bad, governs the ditch backbone

project and the middle and small scale dam disposition proportion wants high somewhat relatively; The soft rock area by the loess, the red soil gentle breeze sandy soil primarily area has the construction dam storehouse condition, the slope face and the trench The soft rock exposed area related constructs the silt arrester and sediment pool the condition and the material pending research.

### 3.1.2 Region construction dam storehouse has the deep mass base

The silt arrester is the loess plateau area populace in the long – term production practice creation conservation of water and soil measure, has provided certain water source condition and the massive high and stable production basic farmland for the populace, enhanced the land productive forces and increases production ability continually, also has facilitated some local countryside transportation, realized has closed off a mountain area the afforestation, seals nurtures under the protection and the cooking oil Sichuan, forestry grass climbs mountains, transfers the populace to govern the soil erosion the enthusiasm. From receives the degree which welcome north, the loess region is higher than the soft rock area and covers the desert region, the south area is higher than the area, the small dam is higher than compares the dam. In the region local all levels of governments take the silt arrester construction, in the organization, the launch, led the populace, the formulation and the promulgation preferential policy and the means, safeguard aspects and so on silt arrester construction and safe operation has also displayed the very high enthusiasm.

The construction sediment pool to the flood prevention flood detention, the effective adjustment and the reasonable use region extremely limited water resources; The development irrigation farming, guarantees the agricultural production increase to additionally receive; Increases the cities, industry and mining enterprise water furnishing ability, alleviates the country dweller livestock potable water to be difficult; Protects the cities, the village, the industry and agriculture production and the populace life and property security, improves the mountain village transportation, the populace has certainly constructs the storehouse enthusiasm.

### 3.1.3 Region construction dam storehouse had very well blocks the putty benefit

Construction silt arrester still take the small basin as a unit, governed the ditch backbone project with, the small dam unifies, the establishment layer upon layer intercepted, the piggy – back governing complete trench preventing and governing measure system, sealed off from the source to the downstream transportation silt channel, has formed an artificial barrier in the silt collection and the channel place. Not only it can the effective peak clipping, the flood detention, retain the slope face to converge in the trench the silt, moreover can raise the basis of erosion, the stable ditch slope, stops the bank to expand effectively, the ditch sole undercuts with a ditch advance, reduces the trench to corrode, blocks the sand (putty) the benefit to be extremely remarkable. The research indicated that, the silt arrester reduces the sand technical progress factor to be higher than other measures by far; The large – scale silt arrester blocks the putty effect to surpass the small silt arrester to block the putty effect; Forms the dam department the silt arrester to block the putty effect to surpass has not formed the dam is the silt arrester blocks the putty effect. But sediment pool to compare the trench dam has the project scale in a big way, the defense standard high, the governing area big, the governing trench rank high, the unit storage capacity invests slightly, blocks a putty effect more remarkable characteristic.

### 3.1.4 Regions govern the slope measure to have widespread development space

This area to have the massive  $5^{\circ} \sim 25^{\circ}$  lands, governed the slope measure for the development to provide the widespread space. Decided level terraced field development quantity the main natural condition is a terrain, decided forest grass development quantity the main factor has the temperature, the precipitation and the soil and so on, this area unique natural condition had decided the region forest grass construction should prohibit the protection, the nature to restore the vegetation primarily, the vegetation construction type fills by the grass primarily, the herb, the bush, the tree unify. Three government area overall degree of cover is low, the vegetation construction needs to

live the tree, the bush suitably according to the different government area and the grass class, Persists to act as circumstances permit, suitably suitable tree (grass) principle. Besides the level terraced field and the partial forage grasses are decided by populace's demand, other the slope governed measure mainly to be decided by the natural condition and the ecology construction demand.

### 3.1.5 Regions govern the slope measure to have well block the putty benefit

Level terraced field to be able to retain the surface runoff effectively, reduces the soil erosion, thus improvement soil nutrient and moisture content condition, increase land productive forces. Not only forest grass may slow down the rainstorm to the surface sputtering, reduces the surface amount of runoff and produces the sand quantity, reduces produces flows the speed and the fluent process peak value, under the extension infiltrates under the time, the increase infiltrates the quantity and the underground amount of runoff, moreover may block reduces silt 40% ~60%. Governs the slope measure the reasonable layout, to governing the slope face own soil erosion, the improvement ecological environment has the extremely remarkable function, simultaneously causes the trench to come the water to come the sand to reduce, the trench cuts the ditch corrosion and the gravity corrosion weakens, enhances the dam to guarantee the harvest rate and dam storehouse flood prevention ability, lengthened has blocked the silt age limit, the safeguard governs the ditch measure long-term, continually, the safe display benefit.

## 3.2 Suggestion

In the synthesis analyzes, the thick silt central source area in middle reaches of Yellow River nature and the economic society condition difference is big, thus had decided the government measure in the loess region, the soft rock area and covers the desert region the applicability to have the big difference.

The loess region constructs the dam condition to be good, the trench engineering construction has formed certain scale, also has completed certain quantity silt arrester department, should govern the ditch backbone project prominently and block the putty storehouse the centralism, blocks the sand function fast; Because this area the population density is big, the slope face use and the development degree are high, the slope face government also develops quickly, should continue to use the small basin comprehensive program of public order pattern.

The soft rock area population density small, the land-use capability is low. This area implements prohibits with the ecology immigration primarily, the reduced jamming, the auxiliary big area sea-buckthorn and so on lives the plant government measure suitably, the promotion ecology restores naturally, at present prohibits the government, the ecology immigration and has formed certain scale using the sea-buckthorn development manual government, should take the next government will have to persist one of directions; This area special geology landform condition, has constructs the dam the topographical condition, may make the field in the population relative many trench implementation river improvement or construct the middle and small scale silt arrester, in has the condition ditch mouth construction to block the putty storehouse to seal the ditch, but the related dam geology, Constructs questions and so on dam material and construction technology waits for the solution.

Covers the desert region to persist the trench government and the slope face government, the water erosion government and the wind erosion government, the manual government and the ecology nature repair pays equal attention to the principle, Should by the vegetation construction and the sandstorm government measure primarily, the attention grass fills the solid sand, the sand barrier blocks the sand; Makes Hong in the trench development to inundate, the pilot pulls the sand building paddies as well as the truncation bends down flows the engineering construction, simultaneously in has the condition trench right amount construction to govern the ditch backbone project and so on.

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# Developing the Ecological Self – rehabilitation Capability and Speeding up the Control and Harnessing of Soil and Water Loss in the Upper and Middle Reaches of the Yellow River

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**Abstract:** The Loess Plateau is facing with more and more serious ecological problems, and developing ecological rehabilitation is obligatory to implementing the scientific view of development. Since 2000, ecological rehabilitation experiments have been actively taken in the selected places in the upper and middle reaches of the Yellow River, and obvious achievements have been made. Some preliminary experiences were obtained, such as making necessary rules and regulations, making unified planning by government, taking various measures simultaneously and strengthening the management and protection, etc. During the “eleventh five year” period, it is necessary to perfect all kinds of measures and to promote the sustainable development of ecological rehabilitation in all-around.

**Key words:** Ecological rehabilitation, water and soil conservation, the upper and middle reaches of the Yellow River

## 1 Remarkable effects on water and soil conservation and ecological rehabilitation in the upper and middle reaches of the Yellow River

### 1.1 Effects of ecological rehabilitation

In order to give full play of ecological self – rehabilitation capability and increase cover degree of vegetation, explore new ways of quick vegetation rehabilitation, and find out new methods for water & soil loss harnessing, all the provinces (autonomous regions) in the upper and middle reaches of the Yellow River have adhered to the new ideas of water control instructed by the Ministry of Water Resources since 2000. While taking the actual situation of the Loess Plateau into consideration, each province put the water & soil conservation and ecological self – rehabilitation into practice as an essential work for ecological environment construction, and actively carried out the ecological rehabilitation experiments in the selected places. In 2001, the Yellow River Conservancy Commission (YRCC) started up two pilot projects of water & soil conservation and ecological rehabilitation in the upper and middle reaches of the Yellow River, covering 7 provinces (autonomous region), 20 counties (banners) and a closure and protection area of 1,300 km<sup>2</sup>. Based on the experiences obtained from the first – phase pilot projects the Ministry of Water Resources started up the national pilot projects of water & soil conservation and ecological rehabilitation in 2001, covering 7 provinces and 22 counties with a total area of 6,300 km<sup>2</sup>. Presently, in the seven provinces in the upper and middle reaches of the Yellow River, closure of nature reserve is carried out in 54 prefecture – level cities and 294 counties (cities and banners) with the closure area of about 300 thousand km<sup>2</sup>. The governments of Shaanxi Province, Qinghai Province, Ningxia Autonomous Region have promulgated the administrative orders of hill-closure and prohibition of grazing. The same policy has appeared publicly in 36 cities and 168 counties (banners and prefectures) in Shanxi Province, Inner Mongolia Autonomous Region, Gansu Province and Henan Province. Guard works for protecting water and soil conservation have been constructed within the source area (120 thousand km<sup>2</sup>) of the Yellow River in Qinghai Province. The scale, scope and effect of hill – closure and prohibition of grazing in the upper and middle



reaches of the Yellow River came to its highest level ever met in the history.

### **1.1.1 Increase of forest and grassland cover rate, and improvement of ecological environment**

Since ecological rehabilitation implemented, the growth speed of shrub – grass vegetation in the rehabilitation zone obviously became faster, crown closure naturally appeared on bare soils, moreover, vegetation cover rate increased greatly and ecological environment improved obviously. According to the monitoring results from 24 pilot counties, within the rehabilitation zones, the area with the forest and grassland overall cover rate higher than 0.6 increased to 1,262 km<sup>2</sup> from the original 297 km<sup>2</sup>, the forest and grassland cover rate increased to 60% from the original 27.5%, the average grasses yield per hectare increased to 30 000 kg from the original 3 000 kg. Vegetation became complex and diversified instead of the original single species. The most obvious change of the project area was that the hills turned to be green and water to be clean, meanwhile, the quantity and species of animals increased visibly. After three years of rehabilitation, in Yanchi County and Lingwu County, Ningxia, the sandstorm disasters have been basically controlled, the jointed large area of sandy lands and sand dunes basically disappeared, and besides, the strong windstorms in winter and spring were basically controlled, and the water and soil loss intensity obvious became lower.

### **1.1.2 Increase of water and soil conservation benefit, and obvious decrease of water and soil loss intensity**

Through taking the measures, such as hill – closure and prohibition of grazing, replanting in sparse woodlands, returning farmland to grass, and artificial cultivation, etc., the aboveground biomass and litter fall increased obviously. More than that, much water could be retained by vegetation and much runoff could be impounded by soil, resulting in the obvious decrease of water and soil loss intensity. According to the analysis of monitoring data, after three – year hill – closure and prohibition of grazing in Wuqi County, Shaanxi Province, local annual average soil erosion modulus reduced to 0.6 thousand t/km<sup>2</sup> from the original 1.1 thousand t/km<sup>2</sup>. In some places with severe water and soil loss within the loess area, such as Anding Prefecture (Gansu), Pengyang County (Ningxia), the rainstorm – runoff modulus has reduced by about 40% and the soil erosion modulus reduced by 40% ~ 60%.

### **1.1.3 Promoting the readjustment of rural industrial structure, and transformation of production and operation mode**

Through developing the pilot projects of ecological rehabilitation, the structure of agriculture and crop cultivation and the composition of livestock herds in every rehabilitation zone have changed greatly. Many places have changed to “cultivating crops for breeding livestock, and developing crop cultivation and livestock farming jointly” from the original “grain – oriented farming”. The planted area of silage crops increased greatly. The composition of livestock herds developed towards high – quality breeding, and large quantity of livestock that are fit for yard feeding and have high economic value, such as cow, han – sheep, have been introduced into the rehabilitation zones. In Jungar Banner, Inner Mongolia, 0.1 million farmers gave up crop farming and took high – quality forage grass planting as their main business. They became “grass farmers” in stead of farmer. Meanwhile, the transformation of rural production and operation mode has been greatly promoted by the implementation of “hill – closure and prohibition of grazing” policy. Many farmers and herdsmen began to accept actively the mode of yard feeding and scientific feeding. A number of qualified big companies or local rich families established special stations for purchasing livestock products or processing shops in some villages and counties with relatively concentrated livestock keepers. This has becoming a driving force for the industrialization of local agriculture and livestock farming. The production activity and normal life of most people were not affected very much by ecological rehabilitation. In many places, local economy and income of people increased rapidly by means of taking applicable countermeasures, improving agricultural production conditions, readjusting rural

economic structures, and developing rural industry and tourist industry. Though in some places the livestock quantity decreased during the first – phase of hill – closure and prohibition of grazing, the rate of domestic animals for sale increased obviously along with the enlargement of artificial grass – planting area, the improvement of livestock species and the transformation of feeding mode. The stock farming turned to develop in mode of intensive management instead of the original extensive management, which helped the rapid recovery of stock farming. Before ecological rehabilitation was put into practice, there were 117 rural families engaged in sheep raising in Zhidan County, Shaanxi Province. The product value of a yard – feeding sheep could be 2.5 times of the loose housing one, so the economic benefits increased obviously.

#### **1.1.4 The concept and idea of ecological rehabilitation have been accepted more and more by the society**

Along with the implementation of “hill – closure and prohibition of grazing” policy and with the obvious increase of ecological rehabilitation achievements in recent years, the governments and carders in each level are more and more aware of the importance of ecological rehabilitation and have much clear mind of ecological protection. More and more people accept the concept of “treating nature in a kind way, and let nature recuperate and multiply”. Many farmers and herdsmen are distressed by the hazards resulted from ecological deterioration. They actively support and cooperate with the governments in doing ecological rehabilitation works, and they strongly want the governments to do much in this aspect. Meanwhile, along with the progress of ecological rehabilitation, the governments and competent departments in each level made up mind to recreate a fine ecological environment. Many local governments make much account of closing protection and ecological self – rehabilitation; they treat it as the strategic measures for the sustainable development of society and economy, and they are making every effort to promote the progress.

### **1.2 Accumulating the successful experiences**

#### **1.2.1 Promulgating policies and establishing rules and regulations**

The governments in each level have list the ecological rehabilitation work into their schedule, and promoted its progress by taking administrative measures, economic measures and even legal measures. Many local governments issued policy documents to ensure the smooth progress of ecological rehabilitation. In the “Notice on Prohibition of Grazing for Improvement of Deteriorated Grassland” issued by the People’s Government of Ningxia, it is said that the grasslands and woodlands within Ningxia Autonomous Region is to be entirely closed for recovery, and any people is strictly forbidden to graze livestock on the grasslands and woodlands. In the “Orders on Hill – Closure and Prohibition of Grazing” issued by the People’s Government of Shaanxi Province, it is clearly stipulated that grazing, quarrying, mining and borrow earth are forbidden in the closure and prohibition area, and illegal deforestation, woodland encroachment, wasteland open – up, resin tapping, stripping, uprooting, and nursery plant digging – up are all strictly forbidden. Meanwhile, most of the counties and cities involved in ecological rehabilitation have issued their documents of local policies, laws and regulations regarding closing protection, yard feeding and prohibition of grazing. Most of the villages have worked out their local rules and regulations. These policies, rules and regulations provide a fine environment for the implementation of ecological rehabilitation, and also play an important role in determining the responsibilities of management and protection, restricting unreasonable production and construction activities and reducing artificial damages, which powerfully promote the ecological rehabilitation.

#### **1.2.2 Making unified planning by government, and cooperating with all the parties concerned**

Ecological rehabilitation is a kind of complicated system engineering; therefore, it would be very important to get it under the government’s overall planning, coordination and promotion. In recent years, local governments have paid much attention on strengthening the leadership concerned

with ecological rehabilitation, which has the key theme of hill – closure and prohibition of grazing. In most of counties and townships, leading organizations have been established with the key government leaders acting as the heads of these organizations to jointly work with the departments in charge of agriculture, forest, water conservancy, public security and environment protection. The responsibilities and missions of each department are clearly defined, forming the management and operation systems in mode of “all departments coordinating with each other under the government’s coordination”. Each department plays its role and supports each other to effectively promote the smooth development of ecological rehabilitation, and remarkable achievements have been made thereby. In Ningxia Autonomous Region, a system of “the chief administrative officer assuming chief responsibility” has been established, under which the objectives and responsibilities of each level have been clearly defined. Due to such a system, all the missions could be accurately put into practice level by level.

### 1.2.3 Taking various measures simultaneously to promote ecological rehabilitation

During the course of ecological rehabilitation promotion, many effective measures have been taken in accordance with the actual local conditions. One of these applicable measures is to promote the rehabilitation by means of construction, that is, to strengthen farmland construction, small watershed harnessing, water – source engineering construction, forage base construction, to readjust planting structure, to enhance sci – tech content, and to change the mode of production from the original extensive cultivation to “less planting, high yield, more gain”. In Pengyang County, Longde County (Ningxia), Wuqi County, Zhidan County (Shaanxi), through constructing terrace farmland, forage base and water – source engineering, the area of terrace farmland per capita has come up to 0.14 ~ 0.20 ha and the area of grass planting per family 0.34 ~ 0.40 ha, and all the livestock were kept in mode of yard feeding. Another measure is to determine the quantity of livestock according to the grass yield. That means to control stocking rate by taking multiple measures with the purpose of reducing stocking density on natural pasturelands and seeking the balance between forage grass and livestock. In Heyuan County, Ningxia, based on carrying out the responsibility system of grassland, the local government scientifically checks and ratifies the size of livestock keeping of each herdsman family according to grass yield and stock carrying capacity of different types of pastureland. Taking a village as a basic unit, the local government pursues the policy of balancing the grass yield and the quantity of livestock, and signs the responsibility agreements with herdsman families to define their responsibilities and obligations. Meanwhile, the local government also adjusts the stocking density by using economic levers, that is, to collect less or even do not collect the animal husbandry taxes from the herdsman families whose livestock are kept within the approved quantity, but to collect double taxes from the families whose livestock exceed the approved quantity. More quantity exceed, more taxes to be paid. The third measure is to promote ecological rehabilitation by means of transformation, that is, to transform the traditional mode of grazing to yard feeding or rotation of closing and grazing, to transform the traditional livestock species to high – quality species, and to enlarge the planting area of forage grass. By such means to ensure that ecological rehabilitation could be put into practice in a large range. In the project areas in Gansu and Shaanxi, almost every family has livestock shed and grassland. In the 12 pilot counties in Gansu, Ningxia and Qinghai, there are newly – built livestock sheds of 0.98 million m<sup>2</sup>, grass planting area 0.45 thousand ha, amount of cattle and sheep on hand more than 0.3 million, which is 37% higher than that before implementing the “hill – closure for improving the grassland” policy. The fourth measure is to promote the ecological rehabilitation by means of emigration, that is, to migrate the farmers and herdsman living under extreme bad ecological conditions to small towns and other places with better condition, so as to reduce the ecological load and artificial damage, and to create necessary conditions for ecological recuperation and recovery. In Shanxi Province, totally 230 thousand people living in 2,700 out – of – the – way mountain areas emigrated to other better places in three years, and about 10 thousand km<sup>2</sup> land was closed and protected thereby. The fifth measure is energy substitution, that is, to solve the energy problem of local people and accelerate the ecological rehabilitation through developing methane kitchen range

and firewood – saving kitchen range. In Huangyuan County (Qinghai), Zhang County, Qingshui County, (Gansu), Yanchi County, Haiyuan County (Ningxia), etc. , through energy substitution demonstration, 80% of the farmer households in the rehabilitation zones have begun to use energy – saving kitchen ranges and kang (heatable brick bed), and 10% of the farmer households have built methane generating pits and new – type toilets. By using energy – saving kitchen ranges and kang, fuel material could be saved by 35%. As for the methane gas users, the fuel consumption could be saved by 60% .

#### **1.2.4 Strictly enforcing the laws, and strengthening the management and protection**

The core part of ecological rehabilitation work is management and protection. On this account, besides strictly enforcing the laws on water and soil conservation towards the development and construction projects, local governments have brought ecological rehabilitation into their routine management. Special organizations have been established and relevant rules and regulations have been formulated, more than that, ranger teams have been organized and the responsibilities have been clearly defined. In most places, the propaganda and management service networks have been set up in county, township and village levels. In Erdos (Inner Mongolia), Yan’an (Shaanxi) and some other places, unlawful grazing would be punished seriously, not only the herdsmen and the rangers will be imposed a fine for violation of law, but also the person in charge of that township and village will suffer administrative penalty and economic punishment. In Zhang County, Lingtai County, Heshui County of Gansu Province, “hill – closure management stations” have been set up under local water and soil conservation bureaus. In Lingtai County, rangers are provided with unified sleeve emblems and are required to keep their daily management and supervisory work in record.

#### **1.2.5 Demonstration and propaganda**

In the past few years, the pilot projects of ecological rehabilitation have been positively promoted by rules and policies formulation, program planning and implementation, governmental organization leadership and coordination, as well as people’s participation and etc, fine results have been obtained thereby. Almost all the pilot projects carried out in the first phase achieved success. Many counties and cities have become the model and sample in local places. During the course of ecological rehabilitation, in order to explain the difficult problems that might be met with, local competent departments in charge of water resources and water & soil conservation propagandized the rehabilitation through various kinds of medium, such as newspapers, TV and signboards. Through plenty of propaganda and education activities, local people gradually accepted the concept of ecological rehabilitation. In Erdos, Inner Mongolia, a propaganda team made up by professional technicians and carders went to propagandize ecological rehabilitation village by village. They patiently explained the policies of the state for the farmers, led the farmers and herdsmen readjusting their production structure, educated them to attach importance to ecological environment, and advised them to adopt the mode of yard feeding. Their efforts finally made the local people began to support ecological rehabilitation. In Yawan Village, Lingtai County, Gansu Province, an “ecological room” was built. In the room there were many materials regarding the current situation of water and soil loss and its hazards, ecological protection and construction, as well as the standards and provisions for punishing the violation of laws and bans. Villagers were organized to visit the room and study these materials to improve their consciousness of ecological environment protection. Fine results were obtained from so doing.

#### **1.2.6 Taking monitoring measures to obtain dynamic information**

During the pilot projects implementation, measures have been taken in each place in accordance with actual local conditions to monitor the vegetation recovery rate, soil erosion modulus, biodiversity, and the income of farmer families, etc. , such factors reflected the results of ecological rehabilitation. Through project monitoring, the regular pattern and effects of ecological self – rehabilitation were basically known, which laid the foundation for establishing the benefit

evaluation index system of ecological self – rehabilitation.

## **2 The Loess Plateau is facing with more and more heavy ecological load, and ecological rehabilitation still has a long way to go**

Through summarizing many years' experiences on water & soil conservation and ecological construction, we can see that remarkable achievements have been made. However, there are still many things unsatisfactory, especially in the following two aspects. Firstly, though much attention have been paid to ecological construction, management is still not enough. There are still many human activities seriously disturb and damage the ecological environment. In the many years' ecological construction on the Loess Plateau, remarkable achievements have been made at the cost of great labor force, materials and capital input. However, the fact that the general situation deteriorating along with regional harnessing is still not changed. When one place is harnessed, many other places would still suffer damage and disruption. Not only the development and construction projects may cause new water and soil loss, but also local people often disturb and damage the ecological environment in their daily life and routine production activities. The extensive and predatory mode of production and operation, such as extensive cultivation and continuous grazing, are the main causes of ecological environment deterioration. Some people said that, a sheep takes a pair of scissors (means sheep's mouth) and four hammers (means sheep's hooves) with it, where it goes, where grass disappears. Presently, continuous grazing has become the main human factor that damages the ecological environment. Meanwhile, some human activities, such as randomly digging for black moss and medicinal herbs, severely damage the ecological environment. There are still many cultivated field existing on steep slopes. Investigation shows that there are still more than 4.4 million hectares of hillside – cultivated farmland with slope gradient higher than  $5^{\circ}$  0.46 million hectares of which higher than  $25^{\circ}$ . Secondly, people still do not know and understand the law of nature very well. This could be proved by the fact that vegetation construction is still the biggest problem of water & soil conservation and ecological construction on the Loess Plateau. The 'three low rate' (survival rate, preservation rate, growth rate) remains to be a serious problem of forestation on the Loess Plateau. People say that trees have been planted year by year, but still no forest come into being. The actual forest preservation rate could only be about 15%, resulting in the slow progress and unsatisfactory effects of ecological construction on the Loess Plateau. In order to improve the survival rate of forest, in many places people often overemphasize site preparation while constructing the forests for soil and water conservation, even not hesitate to destroy the origin soil structure and the aboveground natural vegetation. They aimlessly pursue over – high specifications and standards of site preparation, but fail to correctly follow the principle of matching tree species with the sites. Forestation always deviates from the natural distribution patterns of vegetation and soil moisture, and besides, people used to pay more attention to arbor trees than to shrubs. In fact, many natural factors, such as drought and strong wind, together with human factors, such as the contradiction between forest and grazing, as well as other problem occurring at any link of forestation process, may restrict the artificial forestation on the Loess Plateau or bring the forestation to failure. Aimless pursuance of over – high standards of site preparation will make the harnessing cost per unit area increase greatly, e. g., the cost of overall harnessing per square kilometer would be 0.3 ~ 0.5 million Yuan. According to the experience obtained from the pilot projects of the Yellow River ecological rehabilitation, the cost of vegetation rehabilitation per square kilometer would be only 20 ~ 30 thousand Yuan if we take the ecological measures of mainly relying on natural self – rehabilitation with artificial harnessing subsidiary. What is more, it would not be limited by time and technical conditions. The naturally rehabilitated vegetation fit in with its surroundings best, and such vegetation have the most stable structure.

To solve the above problems, we need to make some change in the coming ecological construction. At the same time of carrying out artificial harnessing, we should actively take the rehabilitation measures with the theme of hill – closure and prohibition of grazing. In this way, not only the vegetation construction could be speeded up, but also the funds saved could be invest to the

construction of soil – returning dams and terraced fields. This would be helpful for quickening the Loess Plateau harnessing.

### **3 Perfect all kinds of measures and promote the sustainable development of water & soil conservation and ecological rehabilitation in all – around**

#### **3.1 Do well in ecological rehabilitation programming**

It is necessary to take the ecological rehabilitation programming into the system of water and soil conservation programming, and to perfect the “Program of Water & Soil Conservation and Ecological Rehabilitation in the Yellow River Basin” as soon as possible. After been approved, the program shall be distributed to each province to define the objectives and tasks in the next period. Each province shall also work out the program of water & soil conservation and ecological rehabilitation of its own as soon as possible. After been approved by the provincial people’s governments, the program shall act as the legal base for directing local water & soil conservation and ecological rehabilitation. In the coming few years, the key areas involved in the ecological rehabilitation on the Loess Plateau shall be source areas of rivers, grassland areas, key water sources areas, and the sandy areas along the Great Wall. The target lands of ecological rehabilitation shall be the grasslands with the cover degree of 5% ~ 50% , and the scrub woodlands and sparse woodlands with the cover degree lower than 40%. Meanwhile, the construction of key control and harnessing engineering shall closely adhere to the artificial harnessing and ecological rehabilitation measures, by such means to improve the strength of ecological self – rehabilitation, and bring the force of nature into full play in harnessing of water and soil loss.

#### **3.2 Taking county as the basic level, village as the basic unit and small watershed as the base in the promotion of ecological rehabilitation**

Promotion of ecological rehabilitation relies much on the administration system. Especially, while taking a county as the basic administrative region, the scale of work will be more feasible, the arrangement of work will be easier, and the results will be better. Meanwhile, the essential of ecological rehabilitation is “closing of hillsides”. However, whether the hillsides could be closed as desired depends on whether the daily life and income of local people could be well arranged, and whether the development of local economy could be guaranteed. Under the “people – oriented” principle, we should take small watershed as the base, county as the basic level and village as the basic unit in the promotion of ecological rehabilitation.

#### **3.3 Strengthening the leadership and coordination**

The ecological rehabilitation work involves with the departments of water recourses, animal husbandry, agriculture, forestry, planning and finance, etc. It is necessary to strengthen the leadership and do well in coordination. The government in each level shall work under the unified planning and cooperate with each other. The departments of water resources and water & soil conservation shall always give good advice to the government and work out proper planning, and do well in technical service and supervision to ensure the accurate progress of ecological rehabilitation work. Meanwhile, it is also necessary to strength the cooperation with the parties concerned and win their support and assistance. Efforts should be made to raise fund for ecological rehabilitation and quicken the construction. Especially, the state is pursuing the policy of increase the input for countryside at present, which should be a favor condition for promoting ecological rehabilitation.

#### **3.4 Perfecting the supporting policies, rules and regulations**

In the past years the state has made a number of laws on protection of ecological environment

and control of water and soil loss. However, some provisions and articles were not detailed enough and not pertinent to ecological rehabilitation very much, which brought difficulties to practice. On this account, local governments shall formulate the supporting policies, rules and regulations in accordance with the actual local conditions. The provisions against unlawful exploitation and grazing as well as unreasonable use of water and soil resources should be issued based on the current laws and regulations and in accordance with the characters of ecological self – rehabilitation. Relevant laws, regulations, provisions, and even the local rules and regulations valid for a village shall come into being. The responsibilities of ecological management and protection shall be defined clearly, and the improper human activities shall be restricted. Meanwhile, relevant preferential policies shall be formulated and perfected. The government shall encourage and make compensations for the people who transformed their mode of production or emigrated for ecological reasons, by such means to arouse the enthusiasm of herdsmen and farmer to participate into ecological construction. The government shall also insist on the principle that “participants will be the beneficiaries”, and shall clearly define the responsibilities, obligations and rights regarding ecological rehabilitation to guarantee the interests of local people during rehabilitation implementation.

### **3.5 Strengthening supervision and management**

Efforts shall be made under the support of local governments to clearly define the functions of the local departments of water and soil conservation on supervising and managing the ecological environment, hillsides closure and probation of grazing. Fulltime law – enforcement agencies shall be established, and specially assigned person shall take charge of supervising and managing the ecological rehabilitation. It is necessary to create high – quality ranger teams, and perfect the system of personal responsibility and incentive mechanism for them, by such means to arouse the enthusiasm of rangers and their sense of responsibility.

### **3.6 Improving the theoretical and technical study**

It is necessary to further with relevant academic institutes and universities to pertinently study the mechanism of ecological rehabilitation, key techniques, mode of rehabilitation, and benefit monitoring system, etc. Standards and technical specifications of ecological rehabilitation should be issued as soon as possible to clearly indicate the principles, requirements, criterion and monitoring of water & soil conservation and ecological rehabilitation. This would be helpful for the standardization of ecological rehabilitation management. The monitoring and evaluation of the rehabilitation benefit should be well done to guide and promote the healthy development of water & soil conservation and ecological rehabilitation.

### **3.7 Do further well in propaganda**

Great effort should be made to propagandize the significance of water and soil conservation work for our country’s ecological construction, and enhance the public consciousness of water and soil conservation. What also need to do is to propagandize the importance of ecological rehabilitation for soil erosion control and ecological environment improvement. We shall let people know that it is a better way to rehabilitate vegetations and control water and soil loss by virtue of the great force of nature and the ecological self – rehabilitation capability. In ecological construction, a concept that needs to be completely changed is putting engineering construction at a higher place than that of ecological protection. People shall give up the improper mode of production and live in harmony with nature.

**3.8 We suggest that the state shall promote ecological rehabilitation project as a special project, and solve its “bottle – neck” problem of funds**

No matter from the view of national ecological safety, or from the view of solving the problem of ‘agriculture, peasants and countryside’ and constructing the socialist new countryside, ecological rehabilitation is an important work worthy of promotion.



## Analysis of Cause for Water and Sediment Variation in Yangjiagou Watershed \*

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**Abstract:** Yangjiagou, a tributary gully in Nanxiaohegou watershed, was determined as a pilot area for small watershed management in 1954. It was aimed to study the effect of soil and water conservation measures on runoff and sediment yield in small watershed by contrast with uncontrolled Dongzhuanggou watershed. Through continual regulation, retention benefit achieved by the soil and water conservation measures played a dramatic role. Analysis of measured data shows that both flood and sediment in Yangjiagou watershed has been on significant rise since the 1980s. This paper makes an analysis of the causes of water and sediment variation in Yangjiagou watershed from the angle of the number and service life of soil and water conservation measures, and draws a conclusion that water and sediment increase in Yangjiagou watershed arises from two factors: first, there has been a slowdown in the number of soil and water conservation measures that play an important role in water and sediment retention; second, the service life of gully control works that yield great returns in soil and water conservation is limited.

**Key words:** runoff variation, sediment variation, typical small watershed, Yangjiagou

### 1 Profile of watershed and arrangement of management measures

Yangjiagou, located in Xifeng District, Qingyang City, Gansu Province, China, is a tributary gully in Nanxiaohegou watershed that is a plateau hilly – gully region in the middle reach of Yellow River with watershed area of 0.87 km<sup>2</sup>. Since 1952, watershed regulation was carried out by taking biological control measures and engineering control measures. In 1954, an observation station was established at basin outlet to monitor water and sediment variation brought by the regulation. Till now, a long series of hydrological data have been accumulated. Meanwhile, another observation station was established in neighboring Dongzhuanggou watershed for the purpose of comparison with Yangjiagou watershed so as to study the water and sediment reduction benefits of the soil and water conservation measures. Dongzhuanggou watershed was similar to Yangjiagou watershed in landform, soil and vegetation conditions, and was in a natural living state. The landform features of the two watersheds are given in Table 1.

Yangjiagou gully correction was initiated in 1952 under the principle of ‘integrated planning, centralized continual regulation, slope – centered gully & slope treatment’ and ‘combing engineering measures with biological measures’. In 1952, regulation work was only carried out in a small part of tablelands. In 1954, correction emphasis was placed on gully in form of closing gully and growing grasses. Till 1958, correction work was fundamentally completed. As stated in Reference, measures taken for Yangjiagou watershed correction were: ① Tableland: 25.07 hm<sup>2</sup> farmland and 1,773 m terrace ridge built; they were all rebuilt into horizontal strip – field before the end of the 1960s; 17.6 thousand of trees were planted along the two sides of paths in the farms in the 1970s; 588m ridge along gully and 1 gully head protection built. ② Hillside: Planting apricot trees was the primary correction measure. 26,400 m horizontal ditch and level terrace were built;

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8.93 hm<sup>2</sup> plantation; 4,643 m field bank in slope land; 2.9 hm<sup>2</sup> level terrace; 1.3 hm<sup>2</sup> artificial pasture land; The rest was forest grassland and non – productive land, covering 8.07 hm<sup>2</sup>. ③ Gully and ravine: Willow check dams were built on gully bottom at the interval of 20 ~ 30 m. Willows were planted between the check dams to form anti – scour forest on gully bottom to prevent oil erosion, fix gully bed, stabilize the angles of both side slopes, and raise erosion base level. Fast – growing locust trees were planted on both banks of colluvial soil. Sallow thorns were planted on the highly sloped debris – slide area of laterite soil. Clovers were grown on gully platform, forming an artificial hay field. 75 check dams built in sub – tributary gullies; 11,000 willows planted; 22.07 hm<sup>2</sup> plantation on gully slopes; 0.41 hm<sup>2</sup> level terrace; 6.13 hm<sup>2</sup> grassland; 7.19 hm<sup>2</sup> natural meadow. Moreover, vegetations recovered rapidly because of the closed management in Yangjiagou.

**Table 1 Landform Features of Yangjiagou and Dongzhuanggou Watersheds**

Watershed		Yangjiagou	Dongzhuanggou
	Total area (km <sup>2</sup> )	0.87	1.15
Tableland	Area (km <sup>2</sup> )	0.30	0.38
	Percent (%)	34.5	33
Hillside	Area (km <sup>2</sup> )	0.208	0.315
	Percent (%)	23.9	27.4
Gulley & Ravine	Area (km <sup>2</sup> )	0.362	0.455
	Percent (%)	41.6	39.6
	Gulley length (m)	1,500	1,600
	Gulley density (km/km <sup>2</sup> )	2.95	
	Gulley gradient (%)	10.67	8.93
	Average width (m)	338	

Interpretation of QuickBird satellite 0.61 m – resolution viewdata, received on June 22, 2004, showed that the present land use status of Yangjiagou watershed was that; terrace farmland, 2.0 hm<sup>2</sup>; high forest, 50.0 hm<sup>2</sup>; shrub forest, 3.0 hm<sup>2</sup>; open woodland, 11.0 hm<sup>2</sup>; under – age plantation, 3.0 hm<sup>2</sup>; natural meadow, 10.0 hm<sup>2</sup>; unavailable land, 6.0hm<sup>2</sup>.

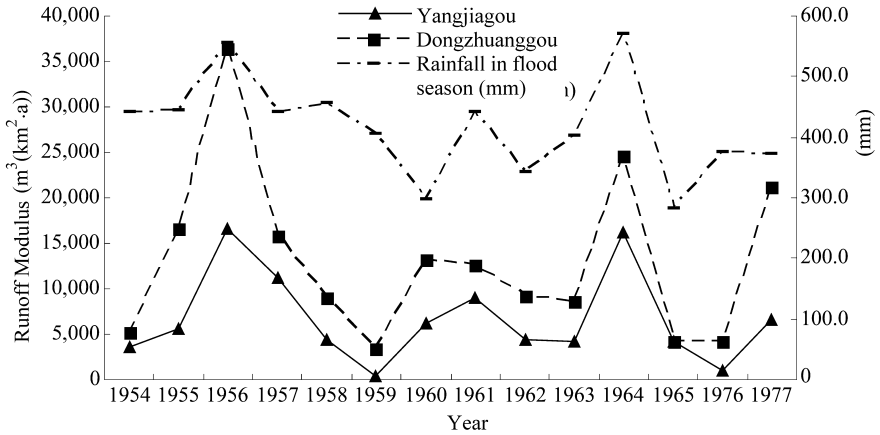
## 2 Analysis of the effect of soil and water conservation measures on runoff yield and confluence in Yangjiagou watershed

According to the analysis of data measured in Yangjiagou and Dongzhuanggou, runoff and sediment yield produced by rainfall in Yangjiagou watershed has a great change after integrated regulation was carried out. Analysis is conducted in details hereunder for the effect of water loss and soil erosion treatment on runoff yield, number of runoff incidences, rainfall excess and daily rainfall flood.

### 2.1 Effect on runoff yield in small watershed

Observation duration in Dongzhuanggou is relatively short. According to the comparison of measured data gained respectively in Yangjiagou and Dongzhuanggou in the same periods (1954 to 1965, 1976 to 1977), implementation of soil and water conservation measures reduced the yearly runoff yield in small watershed. In the case of similar precipitation, annual mean runoff modulus, maximum flood runoff coefficient and sediment runoff modulus were 6,697 m<sup>3</sup>/km<sup>2</sup>, 5.83% and 1,045 t/km<sup>2</sup> respectively in Yangjiagou; and 13,211 m<sup>3</sup>/km<sup>2</sup>, 13.04% and 4,368 t/km<sup>2</sup> respectively in Dongzhuanggou. After regulation, water storage in Yangjiagou was 6,514 m<sup>3</sup>/km<sup>2</sup> more than that in Dongzhuanggou, and sediment quantity in Yangjiagou was 3,323 t/km<sup>2</sup> less than that in Dongzhuanggou. In Yangjiagou, water retention benefit of soil and water conservation

measures was 49.3% , and sediment retention benefit reached 76.1% ( Fig. 1 Table 2 ).



**Fig. 1** Yearly Variations of Precipitation and Runoff Modulus in Yangjiagou and Dongzhuanggou

**Table 2** Comparison of Yearly Runoff Characteristics between Yangjiagou and Dongzhuanggou

Year	Rainfall in Flood Season (mm)	Runoff Modulus (thousand m <sup>3</sup> /(km <sup>2</sup> · a))			Sediment Runoff Modulus (t/(km <sup>2</sup> · a))			Maximum flood runoff coefficient (%)		
		Yangjiagou	Dong zhuang gou	Retention Benefit (%)	Yangjiagou	Dong zhuang gou	Retention Benefit (%)	Yangjiagou	Dong zhuang gou	Retention Benefit (%)
1954	441.5	0.366,4	0.510,2	28.2	167.6	407.0	58.8	2.30	11.50	80.0
1955	445.1	0.553,3	1.664,3	66.8	1,549.4	7,481.7	79.3	7.40	13.00	43.1
1956	554.9	1.651,7	3.630,4	54.5	5,379.3	19,130.4	71.9	8.69	21.70	60.0
1957	440.9	1.114,7	1.587,7	29.8	3,524.1	5,107.5	31.0	12.50	18.20	31.3
1958	456.0	0.431,4	0.898,0	52.0	44.5	1,958.5	97.7	1.96	20.40	90.4
1959	404.1	0.044,5	0.342,9	87.0	5.3	878.1	99.4	0.53	5.09	89.6
1960	297.7	0.625,7	1.313,9	52.4	667.9	4,313.0	84.5	8.52	34.90	75.6
1961	440.6	0.905,4	1.252,2	27.7	171.6	1,080.9	84.1	2.63	3.75	29.9
1962	342.9	0.448,5	0.922,6	51.4	3.5	771.0	99.5	0.37	5.71	93.5
1963	403.4	0.420,5	0.851,1	50.6	37.8	1,456.5	97.4	18.70	7.93	-135.8
1964	568.7	1.618,4	2.453,9	34.0	285.4	4,827.0	94.1	3.72	12.30	69.8
1965	281.7	0.424,7	0.419,2	-1.3	16.8	888.0	98.1	7.91	5.37	-47.3
1976	376.0	0.106,4	0.411,6	74.1	154.6	1,598.3	90.3	0.96	4.81	80.0
1977	370.7	0.663,4	2.124,3	68.8	2,621.8	10,765.2	75.6	5.42	17.90	69.7
Average	416.0	0.669,7	1.321,1	49.3	1,045.0	4,367.5	76.1	5.83	13.04	55.3
$C_p$	0.20	0.74	0.71		1.59	1.21		0.90	0.68	

**Note:** Rainfall in flood season adopts the average value of Shibamutai and Yangjiagou.

After watershed regulation, yearly variations of runoff and sediment quantity increased. Compared with Dongzhuanggou, runoff depth and maximum flood runoff coefficient was smaller in Yangjiagou. However, yearly difference of runoff yield got wide. In the case that the variable coefficient of rainfall in flood season was only 0.20, the variable coefficients of runoff depth, maximum flood runoff coefficient and sediment runoff modulus were 0.74, 0.90 and 1.59

respectively in Yangjiagou, and were 0.71, 0.68 and 1.21 respectively in Dongzhuanggou.

## 2.2 Effect on number of runoff incidences in small watershed

We also conduct a comparative analysis, still on the data measured in Yangjiagou and Dongzhuanggou respectively in the same periods (1954 to 1965, 1976 to 1977) (Table 3), and find out that there also exists a significant difference in the number of runoff incidences between the two watersheds. In the case that rainfall differs insignificantly, yearly average number of runoff incidences is 10.9 times in Yangjiagou, 23.1% below Dongzhuanggou where average number of runoff incidences is 14.2 times. There is no obvious difference in the number of runoff incidences in rainy year and dry year. However, there is the biggest difference in median flow year (Fig. 2). Through frequency analysis by using average precipitation in flood season in Nanxiaohegu watershed, it is known that there appears the biggest difference in the number of runoff incidences when rainfall frequency in flood season is 50% (precipitation is 396.9 mm). For example, in 1959 when precipitation during flood season was 404.1 mm, number of runoff incidences was 20 times in Dongzhuanggou, and only 7 times in Yangjiagou, that is, the difference between the two watersheds was 13 times.

**Table 3 Comparison of Runoff Incidence Number and Sediment Yield between Yangjiagou and Dongzhuanggou**

Item	Time	Rainfall in Flood Season (mm)	Dongzhuanggou	Yangjiagou	Difference	Decrease (%)
Number of Runoff Incidences(times)	1954	441.5	12	9	3.0	25.0
	1955	445.1	16	12	4.0	25.0
	1956	554.9	21	21	0	0
	1957	440.9	9	8	1.0	11.1
	1958	456.0	23	17	6.0	26.1
	1959	404.1	20	7	13.0	65.0
	1960	297.7	8	6	2.0	25.0
	1961	440.6	16	12	4.0	25.0
	1962	342.9	6	4	2.0	33.3
	1963	403.4	8	7	1.0	12.5
	1964	568.7	25	21	4.0	16.0
	1965	281.7	12	12	0	0
	1976	376.0	13	7	6.0	46.2
	1977	370.7	10	10	0	0
	Average	416.0	14.2	10.9	3.3	23.1
Flood modulus ( $m^3/(km^2 \cdot a)$ )	Annual average		13 211	6 697	6 514	49.3
	Submaximum		15 666	6 431	9 234	58.9
Sediment runoff modulus ( $t/(km^2 \cdot a)$ )	Annual average		4 368	1 045	3 323	76.1
	Submaximum		12 221	3 230	8 991	73.6
Maximum sediment concentration( $kg/m^3$ )			1 100	613	487	44.3

**Note:** Comparison Period: 1954 ~ 1965, 1976 ~ 1977.

### 2.3 Effect on annual rainfall excess in small watershed

Most of rainfalls during flood season in loess highland hilly – gully region are rainstorm with great intensity, and produce severe soil and water loss. Compared with Dongzhuanggou watershed, yearly rainfall excess decreased considerably in Yangjiagou watershed. Analysis of measured data showed that yearly average rainfall excess was 280.0 mm in Yangjiagou, 8.4% below Dongzhuanggou where yearly average rainfall excess was 305.6 mm. Especially in 1959, the greatest decrement was 207.2 mm, corresponding to 54.7% reduction. During the 14 years with measured data available, there are 9 years when yearly runoff excess in Yangjiagou was lower than that in Dongzhuanggou, accounting for 64.3% of total number of years with measured data available. Above analysis showed that the benefit of soil and water conservation measures on runoff yield was different in different years. On the whole, implementation of soil and water conservation measures can intercept and retain runoff, and reduce the occurrence of flood.

**Table 4 Statistics of Rainfall Excess in Yangjiagou and Dongzhuanggou**

Year	Rainfall in Flood Season(mm)	Dongzhuanggou Rainfall Excess (mm)	Yangjiagou Rainfall Excess(mm)	Difference (mm)	Reduction (%)
1954	441.5	253.2	214.0	39.2	15.5
1955	445.1	377.4	310.6	66.8	17.7
1956	554.9	453.4	460.0	-6.6	-1.5
1957	440.9	255.3	263.2	-7.9	-3.1
1958	456.0	385.7	303.2	82.5	21.4
1959	404.1	346.9	139.7	207.2	59.7
1960	297.7	238.1	202.5	35.6	15.0
1961	440.6	311.8	365.9	-54.1	-17.4
1962	342.9	103.0	68.1	34.9	33.9
1963	403.4	181.7	128.6	53.1	29.2
1964	568.7	579.9	732.5	-152.6	-26.3
1965	281.7	219.6	241.6	-22.0	-10.0
1976	376.0	285.8	234.4	51.4	18.0
1977	370.7	285.9	256.0	29.9	10.5
Average	416.0	305.6	280.0	25.5	8.4

**Notes:**① Rainfall in season adopts the averaged value of Shibamutai and Yangjiagou;② Rainfall excess occurred three times before May in 1964. So rainfall excess was greater than rainfall during flood season in this year.

### 2.4 Effect on daily rainfall flood in small watershed

After regulation, flood peak flow produced by rainstorm in Yangjiagou was substantially smaller than that in Dongzhuanggou. We selected the maximum peak discharges from each year's data measured in Dongzhuanggou, and contrasted them with those correspondingly selected from data measured in Yangjiagou (Table 5). It can be seen that peak flows were clipped by as high as 66.6% in Yangjiagou. This indicated that soil and water conservation measures over small watershed can control rainstorm flood effectively. The variable coefficient of daily runoff yielding modulus is 1.09 in Yangjiagou watershed, 37 times of that in Dongzhuanggou. The extreme value of runoff yielding modulus is 92 in Yangjiagou, and 34 in Dongzhuanggou. This indicated that watershed regulation led to drastic change of daily rainstorm runoff.

**Table 5 Comparison of Measured Maximum Daily Flood Peak Flow between Yangjiagou and Dongzhuanggou**

Peak Flow Date (y - m - d)	Flood Modulus( $\text{m}^3/(\text{km}^2 \cdot \text{a})$ )				Sediment Modulus( $\text{t}/(\text{km}^2 \cdot \text{a})$ )			
	Dong zhuanggou	Yangjia gou	Difference	Benefit (%)	Dong zhuanggou	Yangjia gou	Difference	Benefit (%)
1954.7.15	1,644.0	1,872.0	-228.0	-13.9	223.0	82.0	141.0	63.2
1955.7.27	5,202.0	927.0	4,275.0	82.2	3 563.0	418.0	3 145.0	88.3
1956.7.2	15,380.0	6,431.0	8,949.0	58.2	12,000.0	3,230.0	8 770.0	73.1
1957.7.24	5,900.0	3,366.0	2,534.0	42.9	1,943.0	1,359.0	584.0	30.1
1958.7.14	1,438.0	198.0	1,240.0	86.2	760.0	27.6	732.4	96.4
1959.9.29	530.0	70.0	460.0	86.8	218.0	1.7	216.3	99.2
1960.8.2	4,818.0	1,133.0	3,685.0	76.5	1 534.0	347.1	1 186.9	77.4
1961.6.30	1,773.0	1,594.0	179.0	10.1	895.0	158.3	736.7	82.3
1962.9.25	1,972.0	231.0	1,741.0	88.3	749.0	3.5	745.5	99.5
1963.5.20	5,950.0	1,533.0	4,417.0	74.2	1,450.0	37.8	1,412.2	97.4
1964.7.20	4,190.0	783.0	3,407.0	81.3	2,523.0	236.8	2,286.2	90.6
1965.7.7	597.0	127.0	470.0	78.7	218.1	6.6	211.5	97.0
1976.8.27	1,584.0	260.0	1,324.0	83.6	618.1	31.2	586.9	95.0
1977.7.5	17,950.0	4,468.0	13,482.0	75.1	9,720.0	2,059.0	7 661.0	78.8
Average	4,923.4	1,642.4	3,281.1	66.6	2,601.0	571.3	2,029.7	78.0
$C_e$	1.09	40.01			21.40	933.38		

Note: Above data are quoted from reference [3].

### 3 Variation of water and sediment runoffs in Yangjiagou watershed

According to measured data, both water and sediment runoffs have been on the rise in Yangjiagou watershed since the 1980s (see Table 6). They descend year by year in 1960s and 1970s, but zoomed up since the 1980s. Comparison between 1980~2004 and 1954~1979 shows that rainfall in flood season reduced by 2.8% while annual mean flood increased by 88.1%, and sediment runoff increased by 95.1%.

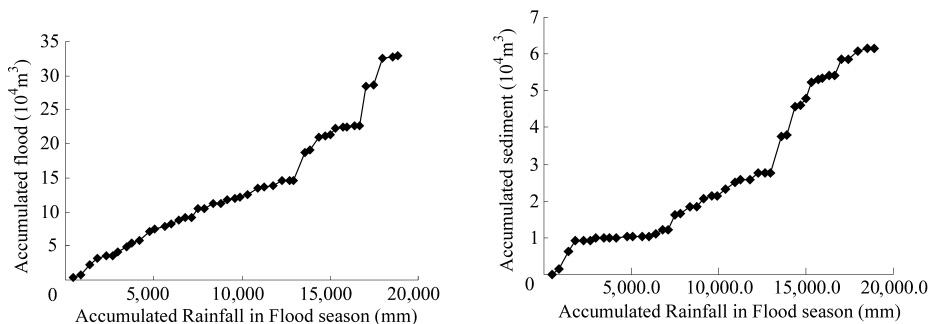
**Table 6 Variation of Water and Sediment Runoffs during Different Periods in Yangjiagou**

Period (year)	Rainfall in Flood Season(mm)			Flood Modulus( $10^4\text{m}^3/\text{km}$ )			Sediment Runoff Modulus ( $\text{t}/\text{km}^2$ )		
	Gauge Data	Reduction	Percent (%)	Gauge Data	Reduction	Percent (%)	Gauge Data	Reduction	Percent (%)
1954~1959	448.1			0.693,7			1,778.4		
1960~1969	412.8	35.2	7.9	0.628,5	0.065 2	9.4	326.7	1,451.7	81.6
1970~1979	395.9	52.2	11.6	0.429,9	0.263,7	38.0	1,338.9	439.5	24.7
(一)1980~1989	419.1	28.9	6.5	0.955,9	-0.262,2	-37.8	2,055.2	-276.8	-15.6
1990~1999	367.7	80.4	17.9	0.509,3	0.184,4	26.6	2,128.6	-350.2	-19.7
2000~2004	440.3	7.8	1.7	2.343,0	-1.649,4	-237.8	1,687.4	91.0	5.1
1954~2004	408.7	39.3	8.8	0.822,4	-0.128,8	-18.6	1,505.1	273.3	15.4
(二)1954~1979	414.4			0.578,6			1,027.0		
1980~2004	402.8	11.7	2.8	1.088,4	-0.509,8	-88.1	2,003.9	-976.9	-95.1

We figure out both rainfall in flood season – flood, and rainfall in flood season – sediment accumulation curves (Fig. 2). It can be seen that the curves present a significant change since the late 1980s (1986). In the rectangular coordinate system, when accumulated rainfall is taken as X – coordinate, the slope of the curve will mean the runoff (sediment runoff) produced by unit rainfall. Therefore, the steeper the accumulation curves are, the larger their slopes are. This reflects that the greater the water and sediment runoffs produced by unit rainfall in watershed are, the less the benefit of integrated watershed correction is. Table 7 provides the fitted relation between accumulated rainfall in flood season and accumulated flood (sediment). In line with water and sediment yielding tendency obtained by using 1984 ~ 1986 serial data in Yangjiagou, till 2004, accumulated flood yield should be 217,393 m<sup>3</sup> in Yangjiagou. However, the actual flood yield was 329,142 m<sup>3</sup>, increasing by 51.4%; Accumulated sediment yield should be 22,158 t. However, the actual sediment yield was 39,358 t, increasing by 56.3%. These data reflect that the retention benefit of the soil and water conservation measures implemented in Yangjiagou has fallen since the late 1980s.

**Table 7 Accumulated Rainfall in Flood Season – Accumulated Flood (Sediment) Relational Expression**

Item	Period (year)	Fitted Formula	Correlation Coefficient
Accumulated Rainfall in Flood Season ( $\sum P_x$ ) – Accumulated Flood ( $\sum W_H$ )	1954 ~ 1986	$\sum W_H = 0.001,1 \sum P_x + 0.974,9$	$R = 0.991,8$
	1986 ~ 2004	$\sum W_H = 0.002,8 \sum P_x - 21.024$	$R = 0.945,3$
Accumulated Rainfall in Flood Season ( $\sum P_x$ ) – Accumulated Sediment Runoff ( $\sum S_H$ )	1954 ~ 1986	$\sum S_H = 0.000,2 \sum P_x + 0.163,2$	$R = 0.967,8$
	1986 ~ 2004	$\sum S_H = 0.000,4 \sum P_x - 1.998,4$	$R = 0.956,0$



**Fig. 2 Accumulated Flood in Flood Season – Accumulated Flood (Sediment) Relation in Yangjiagou**

#### 4 Analysis of cause for water and sediment variation

It can be known from Table 2 that till the 1980s, 14 – year average sediment retention benefit was 76.1%, and water retention benefit was 49.3% by comparison between Yangjiagou and Dongzhuanggou. However, there emerged a great change since the late 1980s. Main causes of such change came from the following two aspects.

#### 4.1 Depletion in number of soil and water conservation measures that play an important role in water and sediment retention

Soil and water loss treatment in Yangjiagou watershed experienced the following stages :1954 to 1957 was the initial stage of watershed regulation. Although regulation benefit was poor in 1954 when rainfall in flood season reached 441.5 mm, the check dams built on the bottom of Yangjiagou gully still played a significant role in sediment retention and reduction water retention benefit of 28.2% and silt retention benefit of 58.8%. During 1955 ~ 1956, the benefits increased greatly with water retention benefit of over 50% and silt retention benefit of over 70%. In 1957, retention benefit decreased with water and silt retention benefits of only 29.8% and 31.0% respectively. Its primary cause was that the soil and water conservation measures were destroyed by a flood occurred in July 24, 1957. As a matter of fact, the rainfall causing this flood in Yangjiagou watershed only had the precipitation of 27.0 mm. However, previous continual rainfall had saturated the soil, so resulting in the largest flood in Yangjiagou and Dongzhuanggou in that year. In Yangjiagou, maximum discharge was  $1.45 \text{ m}^3/\text{s}$ ; maximum sediment concentration,  $528 \text{ kg}/\text{m}^3$ ; flood modulus,  $3,366 \text{ m}^3/\text{km}^2$ , and sediment modulus,  $1,359 \text{ t}/\text{km}^2$  ( In Dongzhuanggou, maximum discharge,  $3.47 \text{ m}^3/\text{s}$ ; maximum sediment concentration,  $550 \text{ kg}/\text{m}^3$ ; flood modulus,  $5,900 \text{ m}^3/\text{km}^2$ ; and sediment modulus,  $1,944 \text{ t}/\text{km}^2$ ). The flood swept away the earth check dams and farm dams in Yangjiagou gully and some fish scale pits and horizontal ditches on slopes, reducing the retention benefit of water and soil conservation measures.

1958 to 1965 was the stable development stage. Large - scale regulation of Yangjiagou watershed was carried out twice from the winter of 1957 to the spring of 1958. Till 1959, various plants had grown more than five years. Thanks to the proper curing, vegetation recovered fast. Both biological measures and engineering measures played a significant role with the silt retention benefit of as high as 84.1% ~ 99.5%. This data fully embodied the advantage of ecological - engineering combination.

After 1967, forests were severely damaged in Yangjiagou (especially, check dams and anti - scour forest on the bottom of the gully were damaged). From the 1970s and the 1980s on, particularly, after the policy of "contracting output quotas to households with the production team conducting unified accounting" was implemented in country, farmers had the right to use the land. Major part of woodland and grassland in tableland area was reclaimed for cultivation. Moreover, those locust trees that were the major species of tree in gully area, and had grown up were cut by local farmers, but not replanted, so that forest density decreased by 70%, and canopy density decreased by 40% in Yangjiagou. Thus, retention benefit reduced a lot since 1980s.

#### 4.2 Decline in retention benefit of soil and water conservation engineering measures

For the integrated correction of Yangjiagou watershed, no other soil and water conversion measures can play such a significant role like engineering measures, which afforded such a rapid and great result. These engineering measures, including fish scale pit, horizontal ditch, gully head protection, earth gully ridge, willow pile check dam, earth check dam and anti - scour forest on gully bottom, were provided to fix gully bed, raise erosion base level, prevent gully bed downcutting, stabilize gully slope, and retain silt and water. Their considerable retention benefit can be ascertained by the contrast between Yangjiagou and Fanjiagou.

As stated in References[5], Fanjiagou watershed has the drainage area of  $0.363 \text{ km}^2$  and the gully gradient of 11.8%. Its centralized correction was initiated in 1955, and mainly based on engineering measures with biological measures as auxiliary method. Till 1961, there had been such achievements, i. e.  $60.2 \text{ hm}^2$  field bank in slope land,  $30.8 \text{ hm}^2$  terrace ridge,  $359.7 \text{ hm}^2$  ridge along gully,  $20.01 \text{ hm}^2$  plantation on gully bottom, 255 fish scale pits, and 147 earth check dams. The runoff yield from 1957 to 1958 in the two watersheds is provided in Table 8.

It can be seen from Table 8 that soil and water retention benefit achieved in Fanjiagou was 62.5% higher than that in Yangjiagou. Especially in 1958, there was 8 - time difference between



the two watersheds. This was because Fanjiagou watershed regulation mainly adopted engineering control measures, e. g. small earth dams and earth check dams, which effectively intercepted and impounded the water inflow. However, on Yangjiagou gully bottom were willow pile check dams, which did not have large retention capacity though their gully securing function was better. Through comparison between the two watersheds, it can be illuminated that engineering measures could produce a greater benefit in soil and water retention in early years. In Table 9, a comparison between two consecutive years for Fanjiagou itself shows that the soil and water conservation benefit was suddenly enhanced in 1958 because engineering control measures were carried out in that year. However, such benefit declined with year – by – year sedimentation.

**Table 8 Comparison of Runoff Yielding Modulus between Yangjiagou and Fanjiagou**

Year	Gully Name	Rainfall in Flood Season (mm)	Runoff ( $m^3$ )	Runoff Yielding Modulus ( $m^3/(km \cdot a)$ )	Maximum Runoff Coefficient (%)	Retention Benefit (%)
1957	Yangjiagou	298.8	8,230.81	9,460.7	9.52	
	Fanjiagou	319.4	2,142.52	5,902.88	7.81	37.6
1958	Yangjiagou	512.7	2,337.88	2,684.23	1.7	
	Fanjiagou	364.9	1,166.02	337.69	0.74	87.4

**Note:** For 1958 rainfall data, July to October period is adopted for Fanjiagou (June data is unavailable), and June to October period is adopted for Yangjiagou. Data source: reference [5].

**Table 9 Comparison of Water Retention Benefit between 1957 and 1958 under the Same Rainfall Condition in Fanjiagou**

Date (y. m. d)	Rainfall Regime		Runoff ( $m^3$ )	Runoff Yielding Modulus ( $m^2/(km^2 \cdot a)$ )	Maximum runoff Coefficient (%)
	Precipitation (mm)	Rainfall Intensity (mm/h)			
1957.7.11	490	19	367.47	1,011.48	2.06
1958.8.11	496	21.6	8.78	23.95	0.048
1957.7.22	55	—	15.86	43.64	0.78
1958.8.9	51	6.3	0.37	1.02	0.02

**Note:** Data source: reference [5].

All engineering control measures were completely built up in Yangjiagou watershed in 1955. From the 1960s, most of these engineering had been filled with silts. Fish scale pits and horizontal ditches were silted up. Gully head protections were heavily damaged. These structures lost their functions in the main, and were not rehabilitated yet. On July 23, 1988, a heavy rainstorm occurred over Nanxiaohegou watershed. Rainfall was as high as 113.4 mm in Yangjiagou. Water rushed into gully from tableland, moving the gully head forward by 0.7 m with true erosion of  $140.5m^3$ . Moreover, 1.5 km gully was incised by 1 ~ 2 m with true erosion of  $3,400 m^3$ , accounting for 45.8% of the total sediment yield in the watershed. According to the survey data of Xifeng Soil and Water Conservation Station, six of the total nine gully head protections were destroyed in Nanxiaohegou watershed (1/3 of them were damaged by human factor; another 1/3 of them were damaged by water inflow that was greater than the retention capacity of these gully head protection works). After gully head protections were destroyed by inflow from tableland, the water rushed into gully, and wash off the earth check dams on gully bottom, augmenting the flood discharge in gully. Meanwhile, outflow carried away part of sediment retained by check dams in the past years. According to the calculation result based on data measured in Dongzhuanggou as shown in References, water rushing into gully from tableland increased erosion modulus by 1.26 ~ 1.4 times. Increased sediment quantity occupied 76.8% ~ 77.9% of the total sediment quantity in

the watershed. Due to above causes, sediment runoff in Yangjiagou in the late 1980 was 95% higher than before. According to our statistics, there were four times of flood with the volume of more than 10,000 m<sup>3</sup> during the period of 1954 to 2004 (Table 10). All these floods occurred after 1988. Obviously, the water and sediment reducing benefit of the soil and water conservation measures has fallen greatly.

**Table 10 Statistics of the flood over 10,000 m<sup>3</sup> at Yangjiagou Observation Station**

Flood Occurrence Date (y · m · d)	Rainfall		Flood			Sediment	
	Precipitation (mm)	Duration (h)	Average Rainfall intensity (mm/h)	Flood Runoff (m <sup>3</sup> )	Maximum Discharge (m <sup>3</sup> /s)	Sediment Runoff (t)	Maximum Sediment Concentration (kg/m <sup>3</sup> )
2000.6.23	59.6	5.47	10.9	48,910	5.5	4,090	107
1988.7.23	97.6	2.17	45.0	33,260	9.99	7,859	379
2002.7.4	64.7	4.03	16.0	27,630	2.79	1,121	108
1992.8.11	22.9	6.63	3.5	13,670	4.89	6,545	681

## 5 Conclusions

Being a tributary gully in Nanxiaohegou watershed, Yangjiagou was determined as a pilot area for small watershed management in 1954. It was aimed to study the effect of soil and water conservation measures on runoff and sediment yield in small watershed by contrast with the uncontrolled Dongzhuanggou watershed. Through continual regulation, Yangjiagou has become a model for watershed correction in loess highland hilly – gully region with plantation as main control measures and engineering measures as auxiliary method. Their retention benefit played a dramatic role, attracting many domestic and foreign experts to visit and research. Nanxiaohegou watershed was established as a national advanced model for soil and water conservation by the Soil and Water Conservation Committee of the State Council in 1957, and was praised as “An Emerald in Loess Plateau” by *People’s Daily* in 1982. The water and soil conservation measures applied in Yangjiagou watershed undoubtedly contributed a lot to such achievements. Analysis of measured data shows that both flood and sediment in Yangjiagou watershed has been on significant rise since 1980s. By comparison between 1980 ~ 2004 and 1954 ~ 1979, rainfall in flood season reduced by 2.8% while annual mean flood increased by 88.1%, and sediment runoff increased by 95.1%. According to analysis of the causes of water and sediment variation in Yangjiagou watershed from the angle of the number and service life of soil and water conservation measures, it can be perceived that: first, there has been a slowdown in the number of soil and water conservation measures that play an important role in water and sediment retention; second, the retention benefit of gully control works has fallen. When gully ridge, willow pile check dam, earth check dam, anti – scour forest on gully bottom, small earth dam and other gully control works operated to its service life, their retention benefit lost due to sedimentation. In addition, the gully head protections damaged by flood were not rehabilitated timely. The sudden increase of runoff and sediment was inevitable even in the watershed with a high canopy density. According to analysis on the retention benefit of soil and water conservation measures in Nanxiaohegou watershed, water and sediment reducing benefit produced by engineering control measures takes up over 90% of total benefit achieved by various soil and water conservation measures. Therefore, attention should be paid to the service life of engineering measures in the biological construction of the Loess Plateau.

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# Effects and Experiences on Key Small Watershed Management of the Yellow River Soil and Water Conservation Ecological Project during the Period of “the Tenth Five – year Plan”

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**Abstract:** Harnessing of 176 small watersheds has been initiated in succession during the period of the Tenth Five – Year Plan for the Yellow River soil and water conservation ecological project, and 1,959.01 km<sup>2</sup> of soil and water loss area has been under primary control. A batch of characteristic modal watersheds has been set up, and remarkable ecological, social and economic benefits have been obtained. Rich experiences have been accumulated in early stage works, project management, mechanism innovation, scientific application, and industry restructuring, setting a good example for soil and water conservation ecological construction on the Loess Plateau.

**Key words:** soil and water conservation, ecological project, small watershed, the Yellow River

## 1 Introduction

For the purpose of speeding up controlling measures for the soil and water loss in the Yellow River Basin, and seeking for new mechanisms, new way of thinking and new measures for soil and water conservation ecological construction under the new situation, and in accordance with the arrangement of the Yellow River Conservancy Commission, Upper and Middle Yellow River Bureau initiated the key small watershed project in 1997, following the guiding principles as follows: emphasizing on coarse sediment producing area, with branch river as the backbone, county area as the unit, and small watershed as the cell.

During the period of the Tenth Five – Year Plan, 176 key small watersheds in the Yellow River Basin have been developed successively, involving 111 counties (cities, banners) in eight provinces (autonomous regions) including Qinghai, Gansu, Ningxia, Inner Mongolia, Shaanxi, Shanxi, Henan, Shandong, with a total area of 6,582.85 km<sup>2</sup>. These small watersheds are distributed in six types of region, namely the loess hilly and gully region, loess plateau gully region, terrace area, mountainous area, sans – blown area, and dry grassland area.

## 2 Achievements

According to statistics, the generally controlled area for soil and water loss accomplished has totaled 1,959.01 km<sup>2</sup> during the Tenth Five – Year Plan, of which prime farmland 27,916 hm<sup>2</sup>, water – conserved forest 91,472 hm<sup>2</sup>, economic forest 29,519 hm<sup>2</sup>, grass planting 19,589 hm<sup>2</sup>, and enclosed grassland 27,405 hm<sup>2</sup>. 143 small and medium scale soil – retaining dams have been set up, and 13,817 small scaled soil and water conservation works have come into being. Now there are 72 key small watersheds passed the final acceptance, 38 of which are appraised as excellent and 34 as satisfactory. What is commendable is that 23 small watersheds have passed the acceptance inspection of the national soil and water conservation ecological environment pilot projects of “Tens – Hundreds – Thousands”, and honored by The Ministry of Water Resources and The Ministry of Finance of PRC. Implementation of key small watershed project has greatly improved the working and living conditions in rural area where the project locates, improved local ecological environment, alleviated the loss of soil, accelerated the sustainable economic and social development and construction of new socialist countryside, and has achieved outstanding social,

economic and ecological benefits.

### **3 Measures undertaken and experiences**

#### **3.1 Strengthening early stage works, laying a solid foundation**

The key small watershed project has strictly followed the fundamental construction procedure, and started works at the early stage in terms of ‘Interim Provisions of Early Stage Soil and Water Conservation Ecological Construction Works’ issued by the Ministry of Water Resources, and the procedure for examination and approval is fairly standard and rigid. Before project proposal and confirmation, each locality invited qualified design organization to work out small watershed preliminary design, and handed to Upper and Middle Yellow River Bureau for examination, and then the preliminary design was revised and perfected based on specialists’ suggestions and got official reply for implementation. All examined and about – to – be implemented preliminary design for small watershed has reached the designed depth and met relevant specifications, and the concept for project construction and the set target is clear. The content and scale of construction is basically in accordance with the reality; measures taken and layout are rational; technical lines are feasible with good operability. All these have laid a solid foundation for the implementation of small watershed project.

#### **3.2 Pushing forward “Three Systems”, and standardizing project management**

In accordance with the state requirements on fundamental construction project management, the legal – person – responsibility – system and project supervisory system have been applied to all the key small watershed project construction, and some major projects adopt bid and tendering system. The first is to thoroughly implement legal – person – responsibility – system. As project undertaking unit, each county soil & water resources and conservation bureau is responsible for organization and implementation of project, works out annual implementation plan, actual budget, statistical forms, application for rendering accounts, and etc., and to make guidance, management and supervision during the whole process of project construction. The second is to totally practice project supervisory system. All supervision job of the project is undertaken by Xi’an Yellow River Engineering Project Management Co., Ltd. and Yellow River Engineering Consultation Project Management Co., Ltd. The supervising engineers control the project quality, progress and investment through site supervision, and put the project quality on the first place of supervision, and quality of measures taken has been well controlled by their conscientiousness job as a consequence. The third is to try out the bid and tendering system. Since key small watershed project belongs to the national investment grant project, bid and tendering system and negotiated bidding has only been tried out in construction of part of terrace and soil – retaining dam. In 2004, Jingning County of Gansu Province invited public bidding of its mechanized terrace, and chose outstanding mechanical execution team to accept mass supervision. And in the same year, Lintao County selected Ningxia Mechanical Service Co., Ltd. and Mechanical Team of Lintao County as the construction unit for its terrace construction through public bidding, and 227 hm<sup>2</sup> high quality mechanized terrace was completed within the year. The competitive mechanism has been introduced through public bidding and tendering, which is convenient for project undertaking unit to invite qualified construction team with high – technical level, thus insuring the construction progress and quality.

#### **3.3 Emphasizing policy guidance, and raising funds through various channels**

Since the national investment grant for the key small watershed project is comparatively lower, and the project executors are mostly from poverty area, the supporting funds by locality have difficulty in reaching its designated position. In order to guarantee some amount of investment for the project construction and construction progress and quality, each locality has found out every possible way to raise funds through various tunnels. One way is to formulate and publicize

preferential policies to attract social funds for small watershed management; another is to integrate relevant items by strengthening unified planning and coordination. Lingshi County and Ji County of Shanxi Province applied measure called ‘nongovernmental orientation and market operation’ to encourage the masses, institutions, enterprises, social organizations to buy, rent and contract in ‘four kinds of waste land’, and adopted four measures to develop manorial mode and large contractors for soil and water conservation. The four measures are as follows; attracting large contractors through preferential policy; gather large contractors together by project construction funds; keeping large contractors by stabilizing property right; giving support to large contractors via high quality service. The two counties have invested 5.5 million Yuan to attract more 60 manorial and large contractors to the project area in succession, and 474 hm<sup>2</sup> soil and water area has been under control, the experience of which could be used for reference for key small watershed construction. Implementation for managing small watershed of Maowangju, Liulin County is promoted and accelerated through policy as “A coal mine, a ditch” as well as by large soil and water conservation contractors. There are three coal mines in the watershed area of Luojiapo, and with requirements put forward by the county government specified for coal mine enterprises governed by the county, one coal mine should provide funds for management of one mountain or one ditch. These three coal mines have made financial contribution of 1.3 million Yuan for management of two mountains around the mining area, totally of 266.67 hm<sup>2</sup>. A big civil entrepreneur in the watershed area bought 266.67 hm<sup>2</sup> of ‘four kinds of waste land’ with 40,000 Yuan, and has totally invested more than 0.7 million Yuan in the following several years. The total area of soil erosion under his control has reached 173 hm<sup>2</sup>. Impelled by his activity, another eight big contractors have emerged. Small watershed of Zhangcungou in Shan County of Henan Province has developed land area for 280,000 Yuan, returning house site to cultivation land of 66.7 hm<sup>2</sup>, conforming the item of returning cultivation land to forest, and raised economic forest of 66.7 hm<sup>2</sup>. In managing Yancha small watershed undertaken by Ansai County, Shaanxi Province, self – employed household, Shi Yun, has provided more than 300,000 Yuan for 34 hm<sup>2</sup> farmland conservancy, and planted 800,000 trees for soil and water conservation. Yangsichuan watershed in Lintao County, Gansu Province has made use of the item of returning cultivation land to forest for fulfillment of 149 hm<sup>2</sup> high forest with soil protecting wood.

### 3.4 Harnessing by professional team, and improving project quality

For the sake of ensuring the project quality and forestation survival rate, some units undertaking project put professional building team into service through years’ practice. Following managing and operating mode of market economy, some counties in Shanxi and Shaanxi provinces have organized professional building teams for soil and water conservation. The teams keep separate accounts with autonomous management, assuming full responsibilities for profits and losses, and undertake construction of mechanized terrace, dry well, soil – retaining dam, miter gates and highforest with soil protecting wood in small watershed harness. For harnessing of key small watershed, 12 counties in Shanxi Province have set up professional building teams, as much as 60 with over 2,000 labour. Giving play to its superiority, Ruicheng County organized a professional team composed of young adults, strong, hard bitten, with good characters and high techniques. The team undertakes ecological project construction for soil and water conservation especially in small watershed area. After the construction scheme has been sent down, the project construction unit would sign a “three – fix and one – guarantee” contract with the professional team – that is, fix on task, fix on standard, fix on cost, and guarantee for survival rate. The contract would define the construction tasks that the professional team should be responsible to accomplish, such as terrace, soil – retaining dam, highforest with soil protecting wood, and etc., and the unit would pay the construction expenditure according to the construction quality and keeping state. Due to the skilled professional team and efficient measures taken, small watershed harness is speedy and of high quality. Luojiapo harness spot of Maowangju watershed in Liulin County has been taken charge by only one professional building team, with a coordinated process from land preparation to planting.

The team's high quality job has caused a high survival rate of planted trees and grass, over 95%.

### 3.5 Popularizing operative technology, and improving scientific degree

Aiming at constructing high - standard and scientific demonstration project, each locality has put much attention on spreading and application of new technologies and improved varieties, such as water - saving irrigation, runoff forestry, mulching film technology, anti - drought forestation technique, and etc. . Small watershed of Yujiacha in Dingxi City of Gansu Province has made great effort in popularizing its experience of 'land preparation a season in advance, and forestation every other season', to guarantee forestation survival rate. While using Genbao, ATP rhizocaline and some anti - drought forestation techniques, for example, dipping root in mud, stem - shoot plantation, ball planting, and mulching film planting, the survival ratio of forestation has been increased. At the same time, Yujiacha has introduced and spread high grade economic fruit trees, including sallow thorn, peach, and apricot. In facing situations of 'three lows' in trees and grass planting, i. e. low survival ration, low retained rate, low benefit, Shanxi Province has taken an active attitude in spreading its seedling technique of 'nourishing vessel' that caused the survival rate up to 80%. Ji County, Zhongyang County and Shilou County of Shanxi Province adopt different planting method by bionomics of species and achieved obvious results. For example, acacia is planted in autumn by stem - shoot technology, and soil be trampled during winter, which causes a survival ratio of 90% or over. And Chinese pine will be timely planted raising seedling in nutrition - pocket during spring or rainy season, which may obviously improve the survival and retained rate. Zhangcungou small watershed of Shan County of Henan Province has adopted black alum to speed up soil fertilizing, and the constructed terrace is of high yield in the following year. In harnessing of Yinmahe small watershed, Guyuan City of Ningxia has greatly applied technologies of stem - shoot, mulching film anti - drought forestation, water saving irrigation, and soil fertility improvement of new terrace field to improve the scientific degree in comprehensive harnessing of the watershed as well as the project quality and standard.

### 3.6 Giving prominence to local characteristics, and promoting economic development

In harnessing of small watersheds, each locality has made great effort in developing local characteristic industry and accelerating economic development, by combing the actuality of watershed and local industrial restructuring. Watershed of Shuangbaozigou of Zhuanglang County, Gansu Province has stick to its way of development by combing harnessing and development. In one aspect, projects for basic facilities such as small - scale lift irrigation system, drinking water engineering and road construction have been developed around dam and reservoir, creating preconditions for comprehensive development of high - efficient ecological agriculture. And in another, terrace has been used for deep development of characteristic industry of potato, fruits, grass and livestock. At present, the areas of the small watershed for developed fruit gardens, economic forest and grass plantation have come to 40 hm<sup>2</sup>, 172 hm<sup>2</sup>, and 405 hm<sup>2</sup> respectively, and more than 700 rain water cellars among the fields have been built up. 8 operative technologies in agriculture, forestry, soil and water conservation, water conservancy and agricultural machinery have been popularized. In 2004, per capita output of grain in the watershed reached 420 kg, and per capita net income 1,330 Yuan. Small watershed of Chenjiagou in Hezheng County grasps its advantageous resources to develop famous regional forestry fruit industry favored by the proper climatic condition, one best known is Pite, which is called kind of pear in local area. After complete returning husbandry to grass, the small watershed of Shiyougou in Yanchuan County, Shaanxi Province has paid much more attention on developing grass industry, yields of fresh grass per mu has reached 2,000 kg, with income per mu 400 Yuan, while arousing the enthusiasm of the country farmers and increasing their income, the percentage of vegetational cover has also got improved. Small watersheds of Zhanggoucun in Shan County, Shunyanghe in Yichuan County, and Baimahe in Jiyuan City of Henan Province have put emphasis on developing economic forests of peach, apple, red date and walnut, and achieved obvious results.

# Heavy Metal Pollution and Wetland Protection in the Yellow River Basin

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**Abstract:** Heavy metals are easy to accumulate, difficult to decompose in animal and human being bodies. They strongly poison the human and livestock bodies who live on the banks, since Yellow River is the important drinking water source. There are a lot of plants and microorganisms in the wetlands, they can eliminate and store up heavy metals in the water. The wetlands in Yellow river play an important role in maintaining the ecological balance and protecting people health. There are a lot of wetlands in the source of Yellow River and along it and they were damaged in some degree because people are not aware of importance of wetlands. There are several ways to protect, recover, and reconstruct wetlands.

**Key words:** The Yellow River, heavy metal, pollution, wetlands, protection

## 1 Introduction

Wetlands are the ecological systems made up of seasonal or perennial water – logging and over – moist areas with biological species habiting in them. Common natural wetlands are the marshlands, Shallow lakes, bogs, salt marshes, mudflats and so on. Wetlands have functions such as protecting water source, purifying water quality, storing floodwater for drought control, regulating climate, controlling soil erosion, protecting coast and keeping biodiversity. They are named as “earth kidney”, “natural reservoirs” and “natural species warehouse”. Wetlands, forest and ocean are three ecosystems in the earth. There are lots of wetlands in the source, shoal and estuary of the Yellow River; they are the important parts of the Yellow River ecosystem. Wetland is reported repeatedly in maintaining ecological balance, but study on its role in governing heavy metal pollution in Yellow River is rarely done. This paper reviews the previous study in this filed.

## 2 Present condition of heavy metal pollution in Yellow River

In the up – to – date environment issues, water pollution is inevitable. Water pollution has become worldwide question. Yellow River is the second largest river in China. There are more than 300 millions mu cultivated land and more than 100 millions people in its basin. On the one hand, we have achieved great success in harnessing Yellow River in recent years, and the Yellow River’s drying up has been holden back obviously. On the other hand, the Yellow River water pollution is getting worse and worse at the same time. Because the Yellow River has to accept millions of untreated waste water every year, water pollution is becoming more serious in the grand river today. In the whole river water of with class I, II is less 8.2% in river length, but water of class V is 31.2%; about 1/3 aquatic organism vanished. Many beaches of Yellow River are polluted; 16 percent of the river wetlands in the Yellow River estuary was polluted by. The water pollution in the distributaries of the Yellow River is shocking by the sight, some are becoming a drainage ditch, and fish vanished there, water in them cannot be used to irrigate corps, moreover, people who drink the water from them often die from cancer. According to statistics, among 19 branches in the Yellow River estuary area, 7 are contaminated seriously, five are contaminated gravely, and only one is contaminated gently.

On July, 2001, Wang Shuchong, Minister of Water Resources, put forward a new Yellow



River control target: "No dyke breaching. No drying – up of river channel, No water quality beyond the standard, No further rising of the river bed". That water quality does not go beyond standard has become one of the new ideas of "keep healthy life of the Yellow River" issued by YRCC.

### 3 Hazard of heavy metals

At present, the metal that density goes beyond 5 is called heavy metal. Water is polluted mainly by Hg, Cd, Pb, Cr, Cu, etc. Heavy metals harm the people health, because molecular of them is larger than other metals; among them, the toxicity of the mercury is largest, the cadmium takes second place, and chromium, lead also have toxicity. Trace heavy metal in drinking has toxic accumulation in human body. Concentration of heavy metals that generally produces toxicity ranges from 1 to 10 mg/L, but concentration of mercury and cadmium, which have more toxicity is between 0.01 mg/L and 0.1 mg/L. Some heavy metals could be converted by microorganism into heavy metal compounds which could not be degraded (the mercury could be inverted into methyl mercury). Because heavy metals have characteristics of accumulating effect and being no easy to drain in body of living things, they accumulates, enlarges, and enters finally the animal body in food chain step by step.

There are characteristics of accumulating heavy metals in agricultural products, in livestock products, in aquatic products, especially in fish and shellfish. Profession Wang Jiangzhang former Vice – dean of Chinese Academy of Medical Science Tumor Hospital suggested that about 80% cancer of human being were caused by environmental factor. The Yellow River is the important source of drinking water, if polluted by heavy metals, the people living along the river would be affected gravely. It is impending to stop the heavy metal polluting the Yellow River.

### 4 Water purification by wetlands

The aquatic organisms have strong ability to accumulate heavy metals. The wetland is always a factory which purifies the surface water. It is reported that concentration of heavy metals that accumulated in tissue of wetland plants are more 100,000 times higher than the periphery water. It is also reported by D. W. Fassott that average concentration of cadmium in 32 freshwater organisms are more than 1,000 times higher than vicinal water. Microorganisms are another important role in purifying polluted water. It is studied that bacteria and fungi could be used to absorb heavy metals in polluted water. It is recently reported by the "Times" that a lot of mercury and other heavy metals are accumulated in wetlands for hundreds of years. They are dangerous because these chemical would likely be released if plants in wetlands are naturally burned.

And plants of wetlands are often used to accumulate heavy metals and to purify the polluted water; this method is cheaper and more efficient than other ones. More pollution damaged ecology that human being makes, more attention should be paid to wetlands in basin of the Yellow River; wetlands play an important role in maintaining the ecological balance in Yellow River basin, and in protecting the health of people along the river.

### 5 Mechanism of wetlands purifying water

There are a lot of plants and microorganism in wetlands. The plants grow rapidly, increasing roughness on the surface, slowing down the water flow rate, and accelerating toxicant to subside. The root channels of plants increase filtration of wetlands, and expand its adsorption capacity. Hydrophytes accumulate heavy metals in the form of metal chelate in some parts of their bodies to clear polluted water. Though heavy metals in water can't directly be decomposed by microprobes, they can be reduced, be added methyl group or be got methyl group away. For example, methyl mercury can be transformed into mercury, which is more volatile and less toxicity, by cytoplasmic mercury reductase encoded in plasmid. Microorganisms have enormous surface area, and can absorb a great deal of heavy metals to reduce content of heavy metals in polluted water. Metabolisms of

Microbes, extra-cellular polysaccharide, and chitin etc., take part in the heavy metals adsorption and fixation process. Armstrong discovered that root system of wetland plants such as reed, cattail has powerful conveying function; it can carry oxygen from air through aerenchyma to root system; make a rich oxygen environment, near the root, for aerobic bacteria living in the absence of oxygen. Besides, plant provides microorganism with gigantic physics surface, which is peculiar membrane structure formed with large root system of plant, and it plays an important role in absorbing, filter, and changing pollutants<sup>[10]</sup>. Since heavy metal ion bringing positive electricity, they easily attach themselves to colloid with the negative electricity. In all, that heavy metals moved away from polluted water is a result of the interaction among plants, microorganisms and soils etc in wetlands.

## 6 Present Condition of Wetlands in the Yellow River basin

The Yellow River originates from the north of Ringzhang tableland. The main river course and filiations of the Yellow River twist between mountains and plains. Many big or small marshes come into being with it. So, the resource of the Yellow River wetlands is very abundant. It mainly includes the headwaters wetlands, Norgai steppe wetlands, Ningxia plain wetlands, Inner Mongocia plain wetlands, Maowususha region wetlands, Sanmenxia wetlands, Downstream river course wetlands and Estuary delta wetlands. Some of them have a beautiful name called "Chinese water tower", and some of them have a large quantity of water, luxuriant grass and lots of marshes.

Wetlands were once considered useless, disease-ridden wasteland. The Yellow River wetland is always holding a condition which is plundered irrationally, deuced reclamation and making a land around the sea sometimes. In addition, the weather is becoming warmer and the quantity of the rain is smaller, even a large quantity of sewage are inflowing into the land. The ecological environment in the Yellow River basin has been damaged critically. The wetlands in the Yellow River source area have been in the serious situation. Taking Maduo county for example, which is located at the headwaters of the Yellow River, the first county the Yellow River flowing through. The average altitude of Maduo county is 4,300 memers, where once being called "thousands lakes county" in plateau. In the recent half a century, with the tendency that weather is becoming warmer and warmer, the temperature is becoming higher and higher and the rainfall is becoming smaller and smaller, on the other hand, with the increasing in amount of livestock, the thickness of the grassland is becoming lower gradually. Because of hunting lots of foxes and eagles which are the natural enemy of the voles, the tail of the foxes and eagles can not be found easily, the disaster of voles spread quickly, it becomes the chief reason of damaging the grassland gradually. Above 70% grassland has degenerated, and above 2,800 lakes have been dry now. In this situation, the poor grassland cannot accumulate the water; the area of the wetlands has shrunk year by year. Thousands of ecological refugees have to leave their homeland. After many years development, the original mudflats and nature riversides are changing into farmlands and the places for cultivation. The drying up of Yellow River aggravated the extent of the pollution of the wetlands ecological system and estuary of the Yellow River, decreased the ecological system function of purifying water at the same time. As this result, the offing pollution becomes serious. With increase of the sea level, the wetlands could be flood, so it could aggravate the erosion of coastline. The area of the estuary wetlands decreased year by year. In a word, because of the blind reclamation and alteration to the wetland and excessive utilization to the biological environment of wetlands, the area of the Yellow River wetlands decreased continuously, each function of them is also decreased dramatically.

## 7 How to protect wetlands in Yellow River basin

Wetlands protection of Yellow River is very important to maintain ecological balance, improve ecological condition, realize harmony of human being and nature, boost sustainable development of economy and society. At the same time, wetlands protection is a systematic engineering, so it needs all public to participate in. We should take measures to do following activities:

### **7.1 Accelerating legislation construction on wetlands protection, building and perfecting legal system concerning wetlands protection step by step**

After China joins “world wetland pact” in 1992, The concept of wetlands just present sporadically to several laws. There are laws to go on in developing and utilizing forest and ocean amid such three largest earth ecosystems as forest, ocean and wetlands, with no national law to protect wetland. Legislation lags behind the need of wetlands protection and having no laws to go on may be main cause of leading to wetland’s being seriously damaged. It is urgent to make research of wetland legislation, with the joining of wetlands legislation and relevant laws, and promulgate wetlands protection statute as quickly as possible.

### **7.2 Strengthening public education to enhance public consciousness of wetland protection**

At present, some of enterprises and individuals purse economic development at the cost of wetlands to gain current benefit because they don’t realize the importance of protecting wetland and crisis of gigantic disasters caused by Yellow River pollution. We should make full use of series of mediums to propagandize vigorously the importance of wetlands protection to enhance public consciousness of wetland protection. We should guide people to adhere to sustainable development to treat rightly the relationship between the contemporary and the future, the relationship between current benefit and long term benefit. In order to keep sustainable development, we should work with responsibility for ourselves, society, country as well as offspring.

### **7.3 Making use of modern information technologies to systemically monitoring wetlands in the Yellow River sasin**

In order to protect valley wetlands effectively, we should make use of modern information technologies to systemically undertake research and survey to get actual and dynamic data, build wetland resource database based on the wetland data involved in geology, physiognomy, hydrology and aerography. At the same time, interlocal cooperation should be reinforced to exchange concerned information for uniform action.

### **7.4 Increasing investment to recover wetlands**

For wetland protection, the fund should be invested heavily in implementing ecological recovery project such as withdrawing plantation to wetlands and withdrawing herd to grass at large scale. In addition, we can mound to supply freshwater or to accumulate rainwater, and introduce into tolerated saline tree seed and grass seed in the estuary area. At present, it was investigated by YRCC that 200 square kilometers riverway wetlands damaged by drying up had been restored, which leads to lower reaches riverway wetlands of the Yellow River can succeed steadily.

### **7.5 Continuing to strengthen uniform administration for the Yellow River water resources, reasonably allocating water resource to ensure supply of ecological water.**

The key of wetlands is water. It is essential for wetlands ecological protection to maintain the Yellow River’s main stream stated flux. Since 5th Water and Sand Regulation Examination, the Yellow River delta wetlands was irrigated by about 20 millions of cube water. Inpouring of an abundance of freshwater makes the Yellow River estuary wetlands change. Naked salina before was covered newly by luxuriant vegetation. The atrophic trend of the Yellow River estuary wetlands was being put under control elementarily. All those have active influence on integrity, biodiversity and stability of wetland ecosystem.

## 7.6 Building a large quantities of natural wetland conservation areas

A large of natural wetland conservation areas should be pushed forward in some suitable regions. The wetlands should be protected in some unconditioned region in the name of wetland Park or wild propagation habitat. We should protect the Yellow River headstream wetlands well, where is accumulator of valley water resources to guarantee entire river having definite ecology water as well as restoration of lower riverway. It have important significance compared to mainstream and branches.

## 7.7 Strengthening technology research of recovery, protection, sustainable utilization of wetlands

Wetland protection technology should go ahead at present. Wetland protection is at preliminary phrase and lack very successful technology and examples. The fund investment should be increased and international cooperation should be strengthened to have a bigger breakthrough in technology research of recovery, protection, and sustainable utilization of the Yellow River wetlands.

“Waterfowls sing on the banks of river” reveals touching picture of wetlands beauty. The wetlands protection task of Yellow River is burdensome derived from depiction above. Incomer can resume although former can't be persuaded. Let's begin now to erect intense awareness of wetlands protection, to do work of wetland's recovery and protection better. Let Yellow River wetlands play an important role in harnessing heavy metal pollution, keeping the healthy life of Yellow River and realizing harmonious development between human being and the nature.

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# Study on Newly – increased Water and Soil Loss Amount Caused by the Exploitation and Construction Projects in Wulanmulun River Basin

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**Abstract:** Based on the principle of runoff yield under excess infiltration, the soil infiltration equation and the curve of relations between runoff and sediment on different types of underlying surface are deduced by conducting natural rainfall, rainfall simulation and scouring experiments, and besides, the newly – increased water and soil loss caused by the exploitation and construction projects in Wulanmulun River Basin is analyzed and forecasted, and the forecasting model for such regional water and soil loss is established. The results show that: ①the river – received amount of the debris from construction takes up 67.09% of the total newly – increased water and soil loss amount; ②the key point of controlling the newly – increased water and soil loss is to properly treat the debris generated from coal mining.

**Key words:** the Wulanmulun River, exploitation and construction project, newly – increased water and soil loss, prediction studies

## 1 Introduction

### 1.1 Natural environments

Wulanmulun River is a branch of Kuyehe River (one of the 1st – class tributaries of the Yellow River). Located at the upper reaches of the Kuyehe River, Wulanmulun River has a watershed area of 3,849 km<sup>2</sup>, of which, 3,839 km<sup>2</sup> is under the control of Wangdaohengta Hydrologic Station. The length of the main stream channel is 138.1 km. The area from the river source to Zhuanlongwan is defined as the upper reaches, Zhuanlongwan to Daliuta as the middle reaches, and the rest as the lower reaches. The river involves Ejin Horo Banner, Jungar Banner, Dongsheng District (Inner Mongolia) and Shenmu County (Shaanxi Province).

In the river basin, the average annual temperature is 7.3 °C and the average annual precipitation is 368.2 mm. The precipitation in the period from July to September amounts to 66.8% of annual precipitation. The year – to – year average wind speed is 2.5 ~ 3.6 m/s, with the maximum wind speed of 19 ~ 24 m/s. With the underlying surface condition of dryness, rear vegetation and coarse sand, strong wind always gives rise to sandstorm. Seventeen rain – gauging stations are distributed within the river basin, including Wangdaohengta Station, etc. See Fig. 1.

### 1.2 Introduction of exploitation and construction

In the 13 years from 1986 to 1998, totally 205 projects were constructed in Wulanmulun River Basin successively, including a railway and two coal – transport railway sidings with the total length of 107.3 km, 7 railway stations, 37 bituminous paved roads with the total length of 320.99 km and 24 rural earth roads with the total length of 281 km. Meanwhile, 2 modern industrial sections and a series of other projects serving for coal mining were constructed in the river basin. The municipal

construction of two existing local cities has gained great development. See Table 1 for the details of major exploitation and construction projects.

**Table 1 The Exploitation and Construction Projects in Wulanmulun River Basin**

Type	Project Name	Quantity	Scale of production	Type	Project Name	Quantity	Scale of production		
Coal	$1 \sim 5 \times 10^4$ t/a	45	$100.1 \times 10^4$ t/a	Bituminous paved road	2nd grade	4	62 km		
	$5 \sim 10 \times 10^4$ t/a	45	$311 \times 10^4$ t/a		3rd grade	11	208 km		
	$10 \sim 30 \times 10^4$ t/a	10	$275 \times 10^4$ t/a		Bituminous	15	239.02 km		
	Large surface mine	3	$2,190 \times 10^4$ t/a		Access	7	19 km		
	Large mine	8		Town (City)	Industrial section	2			
Railway	Baotou – Shenmu Line	1	99 km		Town	1			
	Special railway line in mining area	2	8.3 km		City	1			
	Railway station	7		Others	Stone quarry	8	$10.63 \times 10^4$ m <sup>3</sup> /a		
Earth road	Country road	24	281 km		Brick yard	4	$3,800 \times 10^4$ piece/a		
					Auxiliary projects	7		Coking plant	2
								Cement plant	2

### 1.3 Types of the newly – increased water and soil loss

The newly – increased water and soil loss caused by the exploitation and construction projects mainly involves four types. The first type is the water and soil loss caused by debris from construction. It happens when the waste soil and rocks, or their mixtures, generates while exploitation and construction are just randomly piled up without taking any water and soil conservation measures. The second type is the water and soil loss caused by exposed landform. When surface soil structure and ground vegetation are damaged, or soil and bedrock are exposed due to rock and soil excavation during construction or production, the anti-erodibility of the damaged ground surface becomes weaker than that of the original ground surface, and the water and soil loss amount increases thereby. The third type is the water and soil loss caused by artificial landform. It happens when soil and rocks are moved as designed during construction or production and then orderly stacked up at assigned places with required degree of compaction, but no water and soil conservation measures are taken for the surface of waste piles, or the measures taken have not yet come into play. The fourth type is the water and soil loss caused by rift landform. It refers to the wind erosion, water erosion or cave erosion that makes ground vegetation further wither and die off. Such erosions are due to ground depression, surface crack, or disturbed underground water motion caused by underground excavation or exploitation during construction or production. Observations show that the fourth type only leads to little amount of water and soil loss and its erosion mechanism is complicated. In this study, the main sources of the newly – increased water and soil loss caused by the exploitation and construction projects are determined as debris from construction and human – disturbed soil, and exposed landform and artificial landform are to be called as the “human – disturbed soil”.

## 2 Method and Content of Study

The newly – increased water and soil loss amount mainly includes the new water erosion amount caused by debris and ground surface disturbance during exploitation and construction, as and as the loss amount caused by the debris directly coming into the river, as well as the increased wind

erosion amount caused by desertification aggravated by construction activities. The data of the loss amount caused by the debris directly coming into the river could be obtained through investigations.

## 2.1 Analysis of water erosion amount

### 2.1.1 Method introduction

According to the principle of runoff yield under excess infiltration, surface net rainfall is generated when rainfall intensity is greater than infiltration intensity, and the net rainfall moves under the action of hydraulic gradient to form runoff. The infiltration rate and antierodibility of different underlying surfaces are not the same. Under the action of the same rainfall, the aboveground runoff amount and erosion intensity generated would be different thereby. Such differences between the debris, disturbed soil and the original ground would cause new water and soil loss.

### 2.1.2 Related indexes and formulas

#### 1) Indexes

For the convenience of calculation, the exploitation and construction projects are classified as point projects, linear projects and other projects. Typical surveys have been made on all these three kinds of projects. The calculation indexes for each kind of projects are determined based on the overall survey and comprehensive analysis on the findings. In addition, the antierodibility of debris and disturbed soil has been taken into account since it would increase year by year.

#### 2) Formulas

Formulas include the infiltration equation and the relation equation of water and sediment, which are obtained through comprehensive analysis of the results of natural rainfall, rainfall simulation and scouring experiments. Horton's infiltration curve is used, and the equation is  $f = a + be^{-\beta t}$ . The relation equation of water and sediment is  $y = f(x)$ . When runoff amount 'x' is with unit of 'm<sup>3</sup>' and sediment yield 'y' with unit of 't', the relation equation shall be  $y = ax$ .

### 2.1.3 Calculation procedures

#### 1) Calculation of exceed - infiltration runoff

Computational process: ① Selection and processing of rainfall data. Adopt 44 bouts of rainfall which generated flood, and make reduction treatment of the rain - gauge data and the udomograph data in the proportion of rainfall, and work out the rainfall intensity diagram. ② Calculation of the rainfall relating to the exploitation and construction project. For the point project, the rainfall is determined by the linear interpolation of several rain - gauging stations at the project site; for the linear project, the rainfall is determined by Thiessen polygons plotted by all rain - gauging stations within the river basin. ③ Calculation of antecedent precipitation index (API). The formula for calculating API of the runoff - generating rainfall is  $P_{a,t} = KP_{t-1} + K^2P_{t-2} + K^3P_{t-3} + \dots + K^{15}P_{t-15}$ . Based on the *Daily Rainfall Record*, a hydrologic data book, the API of the successive flood - generating rainfall of each rain - gauging station is calculated respectively to act as the data base for calculating the API of construction projects. ④ Calculation of rainfall runoff. In a certain period of time, the runoff amount generated on the underlying surface could be calculated by deducting the infiltration amount from the rainfall amount. Based on the hydrograph I - t of a rainfall, the API Pa and the infiltration intensity curve f - t and infiltration capacity curve F - t of the underlying surface (different type, different gradient) could be calculated by using the steady infiltration method. See Fig. 2 for details.

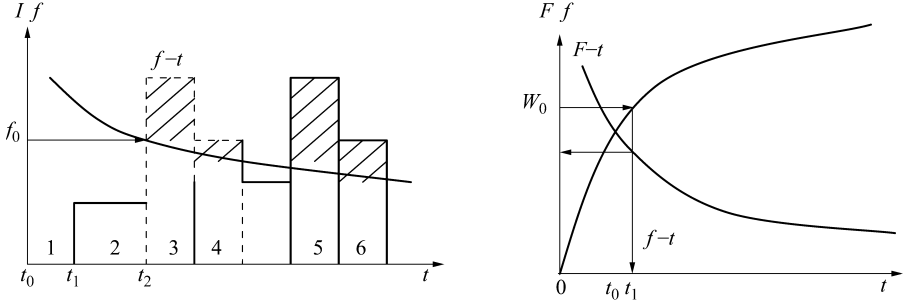
#### 2) Calculation of the newly - increased water and soil loss amount

The newly - increased amount of water and soil loss on an underlying surface (debris or disturbed soil) caused by a construction project is just the dispersion between the erosion amount on this underlying surface and the erosion amount of the original ground under this surface, that is:

$$W_S = W_{S_i} - W_{O_i}$$

in which:  $W_S$  means the newly - increased amount of water and soil loss of an underlying surface;  $W_{S_i}$  means the erosion amount of the underlying surface;  $W_{O_i}$  means the erosion amount of the

original ground under this surface.  $W_s$ ,  $W_{Si}$  and  $W_{0i}$  are respectively determined by using the relational expressions of water and sediment  $W_{Si} = f(R_{Si})$  and  $W_{0i} = f(R_{0i})$ , which are obtained through comprehensively analyzing the results of the natural rainfall, rainfall simulation and scouring experiments.  $R_{Si}$  means the runoff amount on an underlying surface;  $R_{0i}$  means the runoff amount on the original ground under the underlying surface, which is obtained through calculating the excessive - infiltration runoff amount.



**Fig. 2 Schematic diagram of excessive infiltration runoff calculation**

It is known from calculations that, in Wulanmulun River Basin, the loss amount caused by the river - received debris from exploitation and construction is  $3,407 \times 10^4$  t, the water erosion amount of the disturbed soil and other debris sites is  $1,311.21 \times 10^4$  t, and the total water erosion amount is  $4,718.21 \times 10^4$  t. Table 2 shows the newly - increased water erosion amount caused by exploitation and construction.

**Table 2 The newly - increased water erosion amount caused by the exploitation and construction project in Wulanmulun River Basin**

Erosion Type	Project Name	Increased amount( $\times 10^4$ t)			Erosion Tpye	Project Name	Increased amount( $\times 10^4$ t)			
		Distur-bance	Debris	Subtotal			Distur-bance	Debris	Subtotal	
Site erosion	Coal mine; 1 ~ $5 \times 10^4$ t	1. 1	13. 44	14. 54	Site erosion	Brick	1. 32	20. 64	21. 96	
	Coal mine; 5 ~ $10 \times 10^4$ t	1. 47	23. 86	25. 33		Stone quarry	0. 56	8. 81	9. 37	
	Coal mine; 10 ~ $30 \times 10^4$ t	0. 71	54. 39	55. 1		Cement plant	0. 13	—	0. 13	
	Large mine of Shendong Company	49. 25	163. 28	212. 53		Coking plant	0. 08	—	0. 08	
	Railway	52. 18	343. 74	395. 92		Town construction	19. 75	—	19. 75	
	Railway station	2. 66	0	2. 66		Rural construction	25. 17	—	25. 17	
	Bituminous paved road	50. 62	313. 29	363. 91		Site erosion subtotal	282. 88	1,028. 33	1,311. 21	
	Earth road	46. 21	58. 88	105. 09		Loss caused by river-received sediment	Jan. 1986 ~ Dec. 1993	—	3,086. 33	3,086. 33
	Bituminous paved access road	18. 8	23. 65	42. 45			Jan. 1994 ~ Dec. 1998	—	320. 67	320. 67
	Access earth road	5. 83	4. 34	10. 17			Subtotal	—	3,407	3,407
Logistics enterprise	7. 04	0	7. 04	Total	282. 88		4,435. 33	4,718. 21		

**2.2 Analysis on the increased sediment caused by wind erosion**

**2.2.1 Calculation of the river - received sediment amount caused by wind erosion**

1) The relation between wind velocity and sediment discharge of different kinds of underlying surface

The relation equation for six different kinds of underlying surface, established by Lanzhou Desert Research Institute of CAS based on the filed quantitative observation in Shengfu - Dongsheng



mining area, are used, that is:

$$q_i = a \times v^n \quad (1)$$

where:  $q_i$  means sediment discharge, with unit of  $\text{g/cm} \cdot \text{min}$ ;  $v$  means wind velocity, with unit of  $\text{m/s}$ .

#### 2) Wind velocity processing in sediment discharge calculation

In this study, sediment discharges are measured in field observations, and wind velocities are measured at places 2 m higher than ground with time duration of 1 min; however, the wind velocity data issued by weather stations were obtained at the height of 10 m, therefore it is necessary to make corrections for the wind velocity data obtained by anemoscopes at the height of 2 m and in duration of 1 min. The conversion formula for wind velocities at different height is  $V_{10} = k_n \cdot V_n$ , and the conversion formula for wind velocities in different time duration is  $y_{10} = 1.105 + 0.73x_1$ .

#### 3) Sediment discharge in unit width of different underlying surface

The formula for calculating the sediment discharge on different direction within a year in unit width of different underlying surface is:

$$Q_i = q_i \times T_i \times 10^{-3} \quad (2)$$

where:  $Q_i$  means the annual sediment discharge in unit width of an underlying surface, with unit of  $\text{kg/cm} \cdot \text{a}$ ;  $T_i$  means the annual wind time on a direction with wind velocity causing sand movement, with unit of min.

#### 4) Calculation of river - received sediment amount

The river - received sediment amount is not only related to underlying surface and wind force, but also concerned with the direction of river channel and the length and position of various ground surfaces distributing along riverbanks. Under a certain wind force, the river - received sediment amount from the riverside ground surface is directly proportional to the distribution length along riverbanks of such ground surface; in addition, the river - received sediment amount is also directly proportional to the sine of the angle included between wind direction and river channel direction. The formula is as follows

$$\sum Q_i = \sum q_i \times T_i \times 10^{-3} \times \sin\theta \times L_i \quad (3)$$

where:  $\sum Q_i$  means the annually received sediment amount when the distribution length of a kind of ground surface along the river is  $L_i$ ;  $\theta$  means the angle included between wind direction and river channel direction.

### 2.2.2 Estimation of the increased sediment caused by wind erosion

The increased river - received sediment amount caused by exploitation and construction mainly results from the increased wind erosion amount. It is the disturbed soils and debris along riverbanks that make the desertification area enlarged and the activity of sand materials increased, resulting in the above increased wind erosion amount. Estimation is made by the following formula:

$$W_s = (M_{S1} - M_{S2}) \times F \times N \quad (4)$$

where:  $W_s$  means the newly - increased sediment yield generated by wind erosion after mine exploitation;  $M_{S1}$  means the wind - eroded sediment modulus after mine exploitation;  $M_{S2}$  means the wind - eroded sediment modulus on the original aeolian landform;  $F$  means the area of bare ground artificially caused by mine exploitation, which is known through investigation;  $N$  means years estimated. With  $M_{S1}$  and  $M_{S2}$ , the relation equation of wind velocity and sediment discharge (1), the formula of sediment discharge in unit width (2) and the formula of river - received sediment amount (3) could be used respectively while the underlying surface is confirmed, i. e. which type the ground belongs to before and after the disturbance of a project, then the annual river - received sediment amount before and after the construction of this project could be figured out thereby.

It is known from the calculations that the total amount of increased river - received sediment caused by wind erosion, due to exploitation and construction, came to  $360.23 \times 10^4 \text{ t}$ , with annual average amount of  $27.71 \times 10^4 \text{ t}$ . And it is showed that  $327.6 \times 10^4 \text{ t}$  is caused by disturbed soil and  $32.63 \times 10^4 \text{ t}$  by debris.

### 3 Method of forecasting

According to the mechanism of the new water and soil loss caused by exploitation and construction projects, the forecasting methods and model are prepared based on analyzing the soil infiltration equation, the relation equation of water and sediment of slope runoff, and the procedures of loss amount calculation for each kind of underlying surface.

#### 3.1 The coefficient method for newly – increased soil loss

This is a method for forecasting new water and soil loss by taking the soil erosion modulus of the original ground as the base and making use of the soil erosion coefficient of each kind of underlying surface. The relation between the soil erosion coefficient of different underlying surface  $M_i$ , and the soil erosion modulus of the original ground  $M_0$ , is as follows:

$$M_i = k_i M_0 \quad (5)$$

The new soil erosion amount on different underlying surface caused by exploitation and construction project is as follows:

$$\Delta W_i = \gamma F M_0 \quad (6)$$

where:  $k_i$  means the soil erosion coefficient of the kind 'i' underlying surface;  $M_i$  means the erosion modulus of the corresponding underlying surface;  $M_0$  means the soil erosion modulus of the original ground;  $\Delta W$  means the amount of new soil erosion;  $F$  means the river basin area or regional area;  $\gamma$  means the coefficient of new soil erosion,  $\gamma = (1 - k_i)$ . The recommended value for the coefficient of soil erosion and the coefficient of new soil erosion of different underlying surface are shown in Table 3.

**Table 3 The recommended value for the coefficient of new soil erosion of different underlying surfaces, for exploitation and construction projects**

No.	Underlying surface	Results of natural rainfall experiment	Results of rainfall simulation	Range of coefficient of soil erosion, $k_i$	Range of new coefficient of soil erosion	Remarks
1	Original ground	1	1	1	0	Original ground 1110 Original ground refers to the undisturbed sloping land with gradient of $11^\circ \sim 17^\circ$ and vegetation cover degree less than 5%, its erosion modulus is within the range of 8,000 ~ 10,000 t/km <sup>2</sup> . a.
2	Disturbed ground	1.46	2.97	1.4 ~ 3.0	0.4 ~ 2.0	
3	Sandy soil pavement		3.7	3.0 ~ 3.7	2.0 ~ 2.7	
4	Sandy loam soil pavement	2.64 ~ 2.91		2.2 ~ 3.0	1.2 ~ 2.0	
5	Loam soil pavement	2.16		$\leq 2.2$	$\leq 1.2$	
6	Debris (composite)	2.37		$\leq 3.0$	$\leq 2.0$	
7	4 – year debris		2.41	$\leq 2.5$	$\leq 1.5$	
8	Spoil bank of the year	4.49		$\leq 4.5$	$\leq 3.5$	
9	4 – year spoil bank		3.11	3.11	2.11	
10	7 – year debris		1.7	1.7	0.7	
11	Gravel shrub land	0.12		0.12	-0.88	
12	Soft rock (original ground)	0.7		0.7	-0.3	

### 3.2 Mathematical model

Based on the findings of analysis and study, the model for forecasting the annual erosion modulus of different underlying surface is fitted as follows:

$$M = (R, J, Kw) \quad (7)$$

where:  $M$  means annual erosion modulus ( $t/km^2$ );  $R$  means annual rainfall erosivity (m. t. cm/ha. h);  $J$  means ground slope ( $^\circ$ );  $Kw$  means soil anticourability index ( $kg/m^2 \cdot mm$ ).

See Table 4 for the forecasting model of new water and soil loss on different underlying surface caused by exploitation and construction projects.

**Table 4 Forecasting model of annual rainfall erosion modulus**

Underlying surface	Equation	Correlation coefficient $R$
Disturbed	$M = 58.6R^{0.750,7} Kw^{-0.230,5} J^{1.089,6}$	0.898,0
Original	$M = 60.2R^{0.801,8} Kw^{0.023,4} J^{0.653,7}$	0.921,4
Randomly stacked and discard	$M = 517.7R^{0.829,2} Kw^{-0.449,2} J^{0.024,9}$	0.917,6
Randomly stacked and discard (with no gradient)	$M = 564.5R^{0.841,9} Kw^{-0.409,1}$	0.945,0

### 4 Conclusion and Discussion

Based on the above analysis, it is known that, in Wulanmulun River Basin, from 1986 to 1998, the newly - increased amount of river - received sediment caused by exploitation and construction was  $5,078.44 \times 10^4$  t, in which,  $360.23 \times 10^4$  t was resulted from wind erosion,  $1,311.21 \times 10^4$  t from water erosion,  $3,407 \times 10^4$  t from debris directly coming into river. In the total newly - increased loss amount,  $3,714.49 \times 10^4$  t came from coal production system (including debris directly coming into river), account for 73.14% of the total;  $920.2 \times 10^4$  t came from transportation system, account for 18.12% of the total;  $31.47 \times 10^4$  t came from manufacture of building materials, 0.62% of the total; and  $44.92 \times 10^4$  t came from rural and urban construction, 0.88% of the total.

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# Ecological Constructions and Soil Physical Chemistry Characteristics Changing Research in Watershed

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**Abstract:** In ecological constructions in small watershed, the tested results of soil physical chemistry characters at different terrain and vegetation measures reflect directly the factors that influence the change soil physical chemistry indexes and moisture. The research shows that ecological constructions efficiently prevent the soil degenerate succession and promote land sustainable usage.

**Key words:** soil research, soil degenerate, ecological constructions, the Loess Plateau, soil physical chemistry indexes

## 1 Introduction of the experimental area

The experimental monitor area, which is the model district for the Yellow River ecological engineering, locates Suide County of Shaanxi Province, the Yellow River branch Wudinghe River's middle reaches. It's geographical position is between east longitude  $110^{\circ}16' \sim 110^{\circ}26'$  and the north latitude  $37^{\circ}33' \sim 37^{\circ}38'$ . The basin's altitude above sea level is between 820 ~ 1,180 m and total area is 70.7 km<sup>2</sup>, the climate of there belong to the typical arid and half arid monsoon climate, rainfall mainly occur in July to September, occupy 64.4% of the annual rainfall. In the area, the soil texture is loose and the ground is broken, the gully density is 5.34 km/km<sup>2</sup>. The main soil type is the yellow main soil, the underground water depth is about 20 ~ 60. Its slope area is 2,745.01 hm<sup>2</sup> among 4,681.26 hm<sup>2</sup> arable land area in the basin, accounts for 58.6% of total cultivated area. The agricultural production mainly depend on natural rainfall to implement drought made agriculture, the main farming and forestry crops have potato, millet, corn, red jujube, apricot and some mixed fruit class.

## 2 The methods of the experiment

### 2.1 Layout of examination area

According to the experiment goal and the soil characters mensuration standard, we chose 10 plots to analyzing their soil physical chemistry characters and monitoring moisture, form different measure area such as sloping field, terrace and dam - terra and so on. Basic situation of each monitoring plot shows in Table 1.

### 2.2 The contents and methods of examination

#### 2.2.1 The contents of examination

The experiment chooses above 10 plots to monitoring and testing soil interspace degree, bulk density, the moisture degree, the organic matter, available nitrogen, available potassium, available phosphorus and pH volume as well as soil moisture of different time.

#### 2.2.2 The methods of examination

(1) Soil physics indexes, taking soil samples from 10 ~ 20 cm deep soil by core after remove the surface 2 ~ 3 cm deep soil and remains of plants in the selected test field, and test the samples in doors.

(2) Soil chemistry indexes, taking soil samples from 0 ~ 25 cm deep soil using “s” type way after remove the surface 2 ~ 3 cm deep soil and remains of plants in the selected test field, and mixed several plots soil samples together about 1 kg weight, then given dried test in doors.

(3) Soil moisture monitor, with the international advanced soil moisture test – machine — time domain reflector to test soil moisture content, the pastures soil were tested twice every month on 15th and 30th, the soil sampling depth is 20, 30, 50, 100 cm four layers. The forestry soil was tested twice every month on 15th and 30th too, its sampling depth is 20, 30, 50, 100 150, 200 cm six layers.

**Table 1 Basic situation of soil characteristics test areas**

No	Landform and soil style	Slope	Measures	Area
1	Farm sloping field	15° ~ 30°	Castor – oil plant	30 m × 30 m × 3
2	Grass sloping field	15° ~ 25°	Artificial grass	1 m × 1 m × 3
3	Farm terrace	1° ~ 3°	Soybean	30 m × 30 m × 3
4	Farm dam – terra	1° ~ 4°	Sunflower	30 m × 30 m × 3
5	Recovery field	15° ~ 35°	Wilderness	30 m × 30 m × 3
6	Arbor tree sloping field	20° ~ 45°	Oil – pine	30 m × 30 m × 3
7	Shrub sloping field	20° ~ 45°	Violet pagoda tree	30 m × 30 m × 3
8	Economy – forest sloping field	15° ~ 35°	Jujube	30 m × 30 m × 3
9	Economy – forest terrace	2° ~ 5°	Jujube	30 m × 30 m × 3
10	Badland	15° ~ 45°	Wilderness	30 m × 30 m × 3

### 3 The results of the experiment

#### 3.1 Analysis of the tested soil physical chemistry indexes

We chose 1998 and 2003 year’ s soil physical chemistry indexes test result as analysis objective. The details of each item show in Table 2.

From the results of 2 years, we found that each kinds of soil have changed in the physics and chemistry characters during 5 years with different tendency. Among the monitoring lands, the lands that used for farming have obvious degenerated tendency. The order of soil physical chemistry indexes degenerated show in Table 3.

Compared the physical chemistry indexes of the different kinds cultivation managements land, the try bulk density and pH value have little difference from the local theory value. Other indexes especially which have chief influence in the productivity of land using, such as soil interspace degree, available nitrogen, have marked diversity. The farm sloping field, farm terrace and farm dam – terra both have indicated severe degeneration in fertility, only the grass sloping land have some improvement in soil characters.

#### 3.2 Analysis and results of soil moisture at the tested areas

Soil moisture research began after 4 years of construction of “water and soil ecological conservation demonstration area”. The results of soil moisture see in Table 4, and moisture distribution curves see Fig. 1, 2 and 3.

**Table 2 Monitoring soil nutrients at the tested results**

No	Soil types	Try bulk density (g/cm <sup>3</sup> )		Soil interspace degree (%)		Available nitrogen (mg/kg)		Available phosphor (mg/kg)		Available potassium (mg/kg)		pH		Organic matter (g/kg)	
		1998	2003	1998	2003	1998	2003	1998	2003	1998	2003	1998	2003	1998	2003
1	Arbor tree sloping field	1.316	1.324	47.24	49.56	18.3	19.6	18.35	22.89	118.63	124.50	8.61	8.42	4.0	4.2
2	Jujube sloping field	1.337	1.350	50.08	50.52	7.8	8.0	11.82	14.42	133.60	59.85	8.53	8.49	7.4	1.7
3	Shrub sloping field	1.322	1.321	50.02	49.05	11.5	12.7	11.5	14.68	88.95	94.50	8.48	8.43	4.8	2.7
4	Weed land	1.298	1.301	50.06	49.78	7.4	8.2	12.3	14.42	98.36	85.35	8.40	8.40	1.5	1.8
5	Economy terrace	1.388	1.417	46.43	46.01	9.2	10.3	12.27	13.41	131.48	85.50	8.67	8.42	5.3	2.2
6	Farm sloping field	1.332	1.314	51.18	50.20	5.6	4.5	8.1	6.26	93.80	82.40	8.58	8.54	4.6	1.7
7	Grass sloping field	1.285	1.310	49.28	49.97	6.0	7.7	4.46	8.69	91.95	82.55	8.44	8.47	1.9	2.2
8	Farm terrace	1.243	1.226	54.28	53.94	11.2	11.8	13.41	10.36	114.73	88.15	8.42	8.55	5.7	2.0
9	Farm dam – terra	1.249	1.257	51.66	51.56	17.6	15.1	21.46	19.72	93.80	85.75	8.85	8.44	4.6	3.3
10	Badland	1.315	1.301	51.12	50.78	8.1	7.2	10.84	16.42	71.85	88.35	7.80	7.40	3.7	1.5

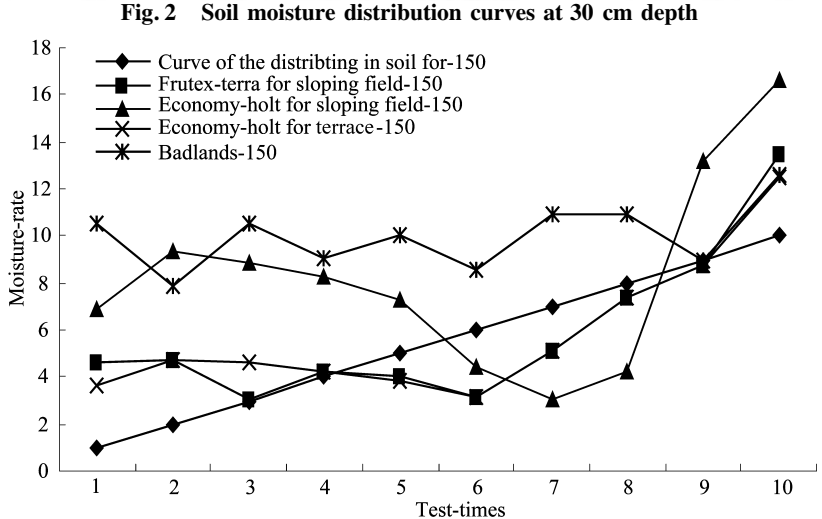
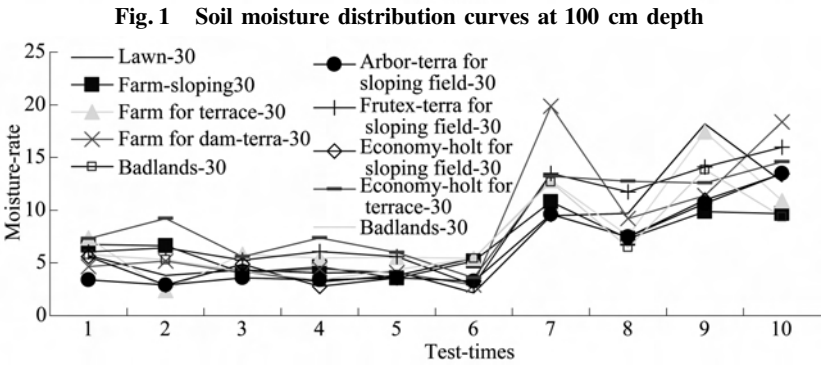
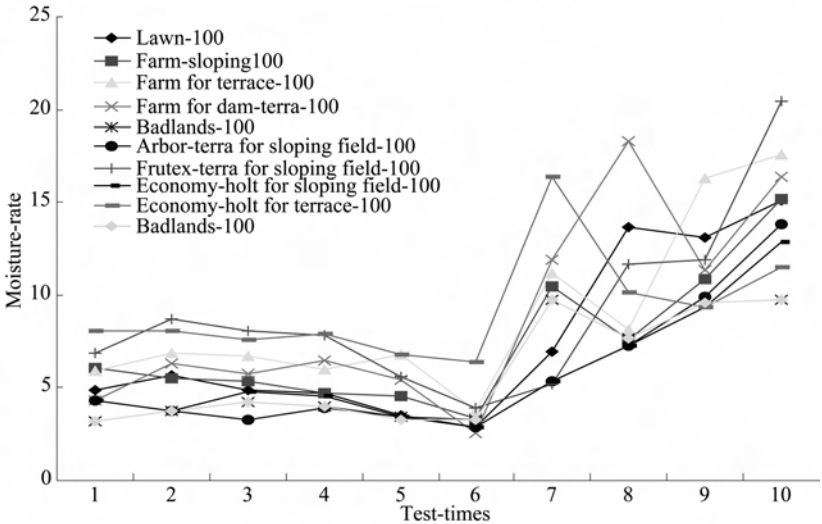
**Table 3 Soil physical chemistry indexes**

Soil type	Dry bulk density (g/cm <sup>3</sup> )	Soil interspace degree (%)	Available nitrogen (mg/kg)	Available phosphor (mg/kg)	Available potassium (mg/kg)	pH	Organic matter (g/kg)
Arbor tree sloping field	6	9	9	9	9	4	8
Jujube sloping field	7	7	4	6	1	6	1
Shrub sloping field	4	2	8	7	8	5	6
Weed land	5	5	6	5	4	7	9
Economy terrace	9	3	7	4	2	3	3
Farm sloping field	1	1	2	3	5	6	4
Grass sloping field	8	8	10	8	6	8	9
Farm terrace	2	4	5	1	3	9	2
Farm dam – terra	6	6	1	2	7	1	7
Badland	3	4	3	10	10	2	5

**Table 4 Soil moisture of the different lands****Unit: %**

Soil types	Depth (cm)	31st May	15th Jun	30th Jun	1st Jul	16th Jul	1st Aug	15th Aug	1st Sep	15th Sep	30th Sep
Weed land		5.68	3.82	4.34	4.03	4.18	2.16	9.48	9.69	18.17	12.72
Farm sloping field		6.77	6.64	4.06	4.63	3.56	5.16	10.8	7.32	9.85	9.68
Farm terrace		7.39	2.38	5.82	5.47	5.54	5.42	12.8	7.58	17.43	10.89
Farm dam – terra		4.66	5.17	4.03	4.42	4.07	2.9	19.86	9.22	11.38	18.36
Badland		5.78	5.32	4.22	3.19	3.83	5.42	12.69	6.48	13.85	9.38
Arbor tree sloping filed	30	3.41	2.92	3.59	3.39	3.58	3.27	9.59	7.48	10.64	13.49
Shrub sloping field		6.06	6.45	5.26	6.09	5.58	2.9	13.48	11.74	14.11	15.97
Economy – forest sloping field		5.58	2.92	4.88	2.78	3.58	3.27	9.59	7.48	10.95	13.44
Economy – forest terrace		7.32	9.22	5.61	7.37	5.99	3.58	13.22	12.75	12.59	14.57
Weed land		4.85	5.69	4.91	4.68	3.5	2.84	6.98	13.69	13.07	15.07
Farm sloping field		6.1	5.55	5.32	4.68	4.57	3.36	10.45	7.6	10.85	15.2
Farm terrace		5.91	6.85	6.67	5.99	6.75	3.77	11.21	8.16	16.28	17.57
Farm dam – terra		4.32	6.33	5.77	6.46	5.4	2.53	11.94	18.29	11.32	16.35
Badland		3.2	3.78	4.2	3.96	3.45	3.31	9.71	7.7	9.61	9.71
Arbor tree sloping field	100	4.33	3.72	3.25	3.93	3.45	2.84	5.37	7.29	9.92	13.84
Shrub sloping filed		6.83	8.74	8.09	7.83	5.57	3.88	5.17	11.63	11.88	20.45
Economy – forest sloping field		4.33	3.74	4.79	4.53	3.45	2.84	5.37	7.29	9.35	12.88
Economy – forest terrace		8.05	8.03	7.59	7.88	6.82	6.36	16.38	10.18	9.35	11.49
Badland	100	3.18	3.78	4.2	3.96	3.29	3.31	9.71	7.7	9.61	9.71
Arbor tree sloping field		4.61	4.68	3.01	4.22	4.02	3.19	5.08	7.33	8.79	13.51
Shrub sloping field		6.84	9.32	8.88	8.22	7.32	4.45	3.09	4.24	13.19	16.62
Economy-forest sloping field	150	3.64	4.69	4.66	4.22	3.82	3.19	5.08	7.33	8.79	12.53
Economy – forest terrace		10.52	7.85	10.48	9.06	10	8.53	10.89	10.89	9	12.55
Badland		3.12	4.39	4.41	4.57	3.64	3.72	2.41	4.92	9.84	14.04

According to the results, the value of monitoring soil moisture between dam – terra, terraced and sloping field decreased significantly, along with the increase of soil depth, the moisture stability became higher. Different kind of plants have different water consumption values at different growth period. Because of the difference of water consumption, the soil moisture are recharged quickly with rainfall in the weed land or artificial grass land which have lower water consumption, but the recharges are very slowly in the field with arbor trees or shrubs which have high water consumption and keep long time of went short of moisture condition. In terrace of the arid Loess Plateau region, there is a general trend that, the soil moisture of flat land is steady and higher relatively, but difference of the soil moisture of sloping field is big, particularly in the field with arbor trees or shrub with higher water demands, the land will in the long – time lower moisture condition.





## **4 Reasonable arrangements of Soil effective use and regulation measure in ecological construction water shed**

### **4.1 To prevent soil erosion and degenerateness, and enhance soil infiltration**

In the general loess knoll gully area, the soil erosion not only makes the soil moisture reduce, but also be the most active factor of the soil degenerateness, and this reduced the moisture's using content seriously. Therefore, the ditch slope renovates, retains into infiltrates is the most important measure in this area for soil degeneration preventing and controlling. Meanwhile plowing deeply and the belt-shaped trench sowing in drought made agriculture may enhance the farmland to retain the precipitation and the moisture content enters infiltrates. According to many years experiment in Yan'an Ansai, just this technology may enhance the crops output 18 ~ 19 percent.

### **4.2 To develop the intensive cultivation, and enhance the effective use of the soil moisture**

The drought made agriculture in the loess knoll gully area, soil hydrologic cycle is gradually retained through the precipitation in the soil, also evaporates by the plant transpiration and the soil consumes, and then retained the precipitation again. Therefore, reducing the soil evaporate and using efficiency measures to enhance soil moisture during plant procreate period can increase soil moisture using efficiency and improve the soil physics and chemistry character, like the fall turns the spring rake, increases executes organic fertilizer, the intercropping and the ground cover and so on.

### **4.3 To follow the order of nature and disposing the vegetation measure effectively**

In the loess knoll gully area, have the arid rain climate, the barren soil and the soil degeneration in the certain degree. We cannot eager for quick success and instant benefit when repairing the ecological environment. Especially in the plant measure disposition, we must fully consider the soil fertility condition and the water resources supporting capacity. Respecting the succession rule of nature, reduce the area on which plant the arbor tree forest with higher water demanding, and increase the lower moisture consumption of grass planted area. Making the big barren land turn green at first, let the soil repaired and improved, then plant trees or bushes on the base of enough water.

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# The Effect of Premium Pasture – sweet Pea on Holding Soil and Water

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**Abstract:** The area of Loess Plateau lacks of vegetation, the water and soil erosion and sand blown by wind are very serious, environment is deteriorating increasingly. At the same time, a great deal of sediment from the up and middle reaches of the Yellow River enter into the Yellow River. As a result, the river bed in the main stream of the lower reaches the Yellow River increases year by year. So we should introduce into some premium vegetable to keep water and soil immediately. Xifeng experimental station for soil and water conservation fetched in sweet pea from middle west of American, according to “the theory of climate similar” and take the experience for 8 years (1998 ~ 2005). They draw a conclusion that Sweet Pea is suitable for ravine of Loess Plateau, and root is deep, as well as, it can cover with most area. Therefore, it can be the premium pasture to conserve water and soil, reduce sediment enter into the Yellow River, improve the condition of environment and the breed of natural pasture.

**Key words:** pasture, sweet pea, water and soil conservation

Plant is the most active one in ecosystem. It can adjust climate, keep water source, conserve soil and water, guard against wind and form sand, purify atmosphere and improve soil fertility. Herbage vegetable has strong adaptability. It can develop in all kinds of awful environment. Sweet Pea is a kind of premium pasture. It was introduced from American during 1998 ~ 2005. After several years planting experiment at Loess Plateau, it has been proved that it is suitable for environment of this region and has perfect function.

## 1 Aims of experiment

The purpose of experience is that acquainting the adaptability of Sweet Pea in ravine of Loess Plateau and the effect of protecting water and soil, improving the benefit of the ecological water and soil conservation project, accelerating local stockbreeding development and improving income of farmers.

## 2 Introduction of the experiment region

Experiment region is built at east lake gardening station of Xifeng City, Gansu Province. It lies in north latitude  $35^{\circ}44'$ , east longitud  $107^{\circ}38'$ . Its altitude is 1,421.9 m. The average rainfall is 561.5 mm and rainfall of July to September occupies 60% of whole year. The average temperature is  $8.3^{\circ}\text{C}$ . The average annual sunlight is 3,060 h. Total radiation  $131\text{ kcal/cm}^3$ . The period of no frost is 162 days. The yearly accumulated temperature of  $\geq 10^{\circ}\text{C}$  is 2,700 ~ 3,300  $^{\circ}\text{C}$ . Experiment ground is black soil. Soil character is silt loam. Soil lacks nutrient. Plant diseases and insect pest is serious.

## 3 Material and method

### 3.1 Material

Sweet Pea introduced from Nebraska in middle west of American, as is shown in Table 1.

**Table 1 Name of lance, producing area and the quality inspection of introduced seed**

English name	breed	latin	Producing area	North latitude	West longitude	climate	Period inthont frost ( month )	Degree of clean ( % )	Weight per thousand particles ( g )	Rate of come up ( % )
Perennial	Sweet Pea	Lathyrus latifolius	Nebraska	41°	100°	Warm, little precipitation, Continent	5	95	50	69

### 3.2 Observation method

Root Distributing: Root distributing observation according to the reference.

## 4 Conclusions and analysis

### 4.1 Phenophase

Comparing Bird's - foot lance with alfafa planted in Loess Plateau, the situation of phenophase is in Table 2.

**Table 2 Phenophase of lance and alfafa**

Name of pasture	Seedtime	Return green	Ramificaion	Exist bud	Anthesis	Legumen	Mature	Scorch	Period of bearing	Period of developing
Lance	04 - 14	03 - 29	04 - 14	05 - 22	06 - 02	06 - 16	07 - 18	11 - 07	111	223
Alfafa	05 - 03	03 - 14	03 - 20	05 - 30	06 - 20	06 - 24	07 - 20	10 - 22	160	223

Lance is planted at the middle of April generally. It can not blossom out and produce at the same year. Since the next year it return green at the last ten day of March. The period of bearing is 111 d, the period of developing is 223 d. The return time is 5 ~ 15 d, it is later than alfafa. The period of bearing is 49 d, it is less than alfafa, while the period of developing is the same. Therefore, lance fit for the local environment.

### 4.2 Analysis of quantity of pasture development

Determination of pasture development is in Table 3.

**Table 3 Height of lance and alfafa****Unit: cm**

Name of pasture	April	May	June	July	August	September	October	Note
Lance	16.8	73.6	122.0	135.0	139.0	142.0	142.0	Length of caudex 300.0
alfafa	—	44.5	77.2	—	—	—	—	

The height of lance is 142 cm, the straight height can be 300 cm. It grows up most quickly in May to June. This period named fast grown period. The time of entering into fast grown period is the same as alfafa, but it grows more quickly than alfafa. Pasture layer is 64.8 cm, it is higher than alfafa.

### 4.3 Analysis of productivity of several pasure

Productivity of lance is in Table 4.

**Table 4 Productivity of lance and alfafa**Unit: t/hm<sup>2</sup>

Name of pasture	First stubble		Second stubble		Overall	
	Fresh weight	Dry weight	Fresh weight	Dry weight	Fresh weight	Dry weight
lance	74.0	14.8	5.9	1.5	79.9	16.3
alfafa	28.8	15.1	9.8	1.9	37.8	17

Fresh grass produced by lance is one times more than alfafa, while dry grass produced by lance is the same as alfafa.

#### 4.4 Ecological value

##### 4.4.1 Remaining of lance

Grass layer of lance is very dense. It can keep most of rainfall. The result of comparing with alfafa is shown in Table 5. Sweet Pea' remaining is 2.7 times larger than alfafa, when at the same age of 4 years, even larger than Hippophae rhamnoides ssp sinensis. The main root is very strong, it has rhizobium which can fix nitrogen and improve soil. All of these are helpful for resisting erosion and osmosis of soil. And it can insure natural function of holding water.

**Table 5 Remainness of Sweet Pea and alfafa**

Name of pasture	Age	Phenophase	remainness(%)	remainness(mm)
Sweet Pea	1	ramificaion	25.19	0.35
	2	legumen	20.53	1.64
	3	legumen	20.11	1.61
alfafa	4	legumen	23.27	1.86
	4	anthesis	19.35	0.7

##### 4.4.2 Root distributing of Sweet Pea

Sweet Pea belongs to straight vegetable of strong root. The quantity, length, cubage and weight of root are listed in Table 6. Table 6 only lists the data of soil layer above 50 cm, others didn't survey.

**Table 6 Root distributing of Sweet Pea**

Layer of soil(cm)	Diameter of root (mm)	root		length		size		weight	
		capita	%	cm	%	cm <sup>3</sup>	%	g	%
0 ~ 10	20 ~ 30	3	1.42	39.9	0.88	40	29.63	58.4	31.33
	5 ~ 20	6	2.84	18.4	1.5	38	28.15	50	26.82
	4 ~ 5	5	2.37	63	1.38	17	12.59	28.6	15.34
	3 ~ 4	6	2.84	75.6	1.66	17	12.59	26.4	14.16
	2 ~ 3	4	1.9	34	0.75	8	5.93	9.6	5.15
	1 ~ 2	9	4.27	94.5	2.07	6	4.44	7	3.43
	<1	178	8.44	4,183	91.76	9	6.67	6.4	3.43

Continued to Table 6

Layer of soil (cm)	Diameter of root (mm)	root		length		size		weight	
		capita	%	cm	%	cm <sup>3</sup>	%	g	%
10 ~ 20	30 ~ 40	2	7.69	32	8.51	60	30.3	202	32.1
	20 ~ 30	4	15.38	60.8	16.18	80	40.4	266.3	42.32
	10 ~ 20	6	23.08	78	20.76	50	25.25	145.7	23.16
	5 ~ 10	1	3.85	16.4	4.37	6	3.03	12.4	1.97
	<1	13	50	188.5	50.17	2	1.01	2.8	0.45
20 ~ 30	20 ~ 30	3	4.29	42	6.01	62	53	215.4	68.19
	5 ~ 20	8	11.43	116	16.59	30	25.64	79.3	25.1
	4 ~ 5	8	11.43	96	13.73	20	17.09	17.7	5.6
	1 ~ 4	5	7.14	36	5.15	2	1.71	1.5	0.47
	<1	46	65.71	409.4	58.54	3	2.56	2	0.63
30 ~ 40	10 ~ 20	4	7.84	48	11.88	41	49.4	112.1	66.93
	5 ~ 10	21	41.12	172.2	112.61	20	24.1	49.1	29.31
	3 ~ 4	6	11.76	68.4	16.93	2	2.41	4.5	2.69
	<1	21	41.18	115.5	28.58	2	2.41	1.8	1.07
40 ~ 50	20 ~ 30	3	3.75	35.4	3.01	30	20.98	80.3	23.01
	10 ~ 20	6	7.5	81.6	6.94	40	27.97	96.8	27.74
	5 ~ 10	10	12.5	121	10.28	35	24.48	76.8	22.01
	4 ~ 5	8	10	92	7.82	14	9.79	42.7	12.23
	1 ~ 4	29	36.25	594.5	50.53	20	13.99	48	13.75
	<1	24	30	252	21.42	4	2.8	4.4	1.26

The root quantity and root length are two important indexes for estimate. The root distribution of Sweet Pea is rather equal. The roots which diameter is larger than 10 cm and can keep soil mainly distribute in soil layer of 10 to 30 cm. The roots which diameter is smaller than 5 mm and can prevent rainwater wash upper land distribute in soil layer of 0 to 10 cm. They have perfect function for water and soil conservation. Meanwhile, they can absorb nutrient and water of soil equally, accelerate the grown of vegetable.

## 5 Conclusions

Lance is suitable for the environment of ravine region in the Loess Plateau. It can finish the process of growing and breeding. It can easily live through winter and summer. Sweet Pea can quickly develop and be very productive in upland. Fresh grass can reach 79.9 t/hm<sup>2</sup>. The stems climb each other, form dense grass layer. Natural height is able to up to at 140 cm. The straight length of stem is more than 3 m. It can accelerate the forest growing which plant together through the function of fixing nitrogen. Sweet Pea has beautiful flower and its florescence is long. So it can be good vegetable for beauty gardens. Its grass layer is very thick. The maximum remaining is 1.86 mm, which is 2.7 times larger than alfalfa. They are even larger than *Hippophae rhamnoides* ssp *sinensis*. The main root is very strong, bigger than alfalfa, it can keep rainwater, reduce wash to land.

Lance has strong root and distributes equally, the main root is very strong. They have rhizobium which can fix nitrogen and improve soil fertility. The roots that diameter larger than 10 cm are in soil layer of 10 to 30 cm and the roots that diameter smaller than 5 mm are in soil layer of 0

to 10 cm. All of this are helpful for resisting erosion and osmosis of soil, which can reduce the water and soil erosion and decrease sediment flowing into the Yellow River. Planting Sweet Pea can adjust the structure of agriculture, restore the ecology of grassland, realize intensive management of husbandry and set up an efficient man – made pasture.

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# **River Engineering and River Ecology**

(I)

## A New Method for Estimating the Instream Ecological Water Requirement

— Ecological Hydraulic Radius Approach \*

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**Abstract:** This essay proposes an ecological hydraulic radius approach (EHRA) which considers both the watercourse information (including hydraulic radius, roughness coefficient and hydraulic gradient) and the required stream velocity necessary for maintenance of certain ecological functions all together. The EHRA not only meets the requirement of flow velocity for adequate fish spawning migration, but also is applicable to the ecological flows in regard with other ecological issues (such as the calculation of the instream flow requirements for transporting sediment (IFRTS) and for pollution self-purification, etc.). It has been illuminated that the computational process taking the estimation of ecological water requirement of Zhuba Hydrological Station watercourse in Niqu branch of the Yalong River as an example. The result shows that the Zhuba Hydrological Station ecological water requirement calculated by EHRA lies between the minimum and favorable instream ecological water requirement (IEWR) calculated by the Tennant approach. This is due to the fact that the ecological flow velocity (such as the fish spawning migration flow velocity) was taken into consideration, producing results applicable to the practical situation. Moreover we defined the permitting flow velocity by the conception of IFRTS, also put forward the ecological hydraulic radius approach (EHRA) to estimate IFRTS. The result shows that the IFRTS occupied 29.7% ~ 59.5% of annual mean discharge in flood season, the average of IFRTS is about 100.2 m<sup>3</sup>/s during 1966 ~ 1987, it is close to the IFRTS 90 m<sup>3</sup>/s calculated by IFRTS conception. Hence, it is feasible to calculate IFRTS by using EHRA.

**Key words:** Ecological Hydraulic Radius (HER), Instream Ecological Water Requirement (IEWR), Instream Flow Requirements for Transporting Sediment (IFRTS), permitting flow velocity

More and more attention has been paid to the ecological (environmental) water requirement with global climatic changing, ecology and environment deteriorating and water resources shortage increasing. So investigations on ecological (environmental) water requirement have stepped into a flourishing period. At present, the theory on ecological water requirement is still at the establishment stage, and in some documentation it is also called as environmental water utilization or ecological and environmental water utilization. However there is not an exact definition till now.

The main purpose to study ecological (environment) water requirement is to actualize the harmony between human society and nature, to avoid human life and production from occupying the ecosystem water requirement and to implement the optimized allocation of water resources in a river basin, and then to provide scientific bases for the realization of sustainable development of

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ecosystem in the basin. Generally speaking, basin ecological water requirement is divided into instream and outstream uses, for further study. This essay mainly focuses on the study of instream ecological water requirement (IEWR).

## 1 Estimation approaches for IEWR

At present, the approaches to calculate the instream ecological water requirement are mainly classified into the following four types: ①Hydrology approach; this approach fixes the minimum flow standard to protect river flow right. It is an off – site style approach, which deduces the recommended value of river flow based on the historical data of the flow rather than the on – site surveyed data. It mainly includes the Tennant approach ( or Montana approach ) , 7Q10 approach and Texas approach. ②Hydraulics approach; With wetted perimeter approach and R2 – CROSS approach as its examples, this approach determines river flow requirement based on hydraulic parameter ( such as width of river, water depth, flow velocity, wetted perimeter, etc. ). ③Habitat approach; with IFIM approach as its typical example, this approach needs to study the fixed hydraulic condition and relevant fish habitat parameter of hydrologic series. ④Holistic approach; with the BBM ( Building Block Methodology ) as its typical representation, this approach has obtained a relatively extensive application in South Africa.

Moreover, Chinese scholars have made an extensive study on refined cleansing water required for diluting contamination, the sediment transport water requirement, the minimum instream water requirement to prevent seawater intrusion and the ecological water requirement of surface evaporation, and have proposed some relevant calculation approaches. Since most studies on river ecological water requirement in China are based on hydrologic data and water quality data, they are lopsided on macroscopic scale and the calculation approaches are not perfect yet.

For a given river, the ideal ecological water requirement calculation approach shall be able to quantify all the parameters and could reflect the interaction among the parameters. So far, such approach does not exist. We must make a careful evaluation when applying any existing approach. Similarity of natural environment and biology plays a very important role for successful application of the approach. Though the sensibility having similar geologic condition and basin area towards low water of two adjacent catchments may differ greatly, so abundant data source support is another requirement for the success of the study.

Based on the above questions, this essay submits the EHRA to estimate instream ecological water requirement taking full advantage of aquatic biological information ( fish spawning migration flow velocity ) and hydraulic information ( non – silting velocity for IFRTS ) and watercourse information ( including water level, discharge, roughness coefficient, etc. ).

## 2 Method and principle

### 2.1 EHRA to estimate IEWR

#### 2.1.1 Assumed preconditions

EHRA and its proposal is mainly aiming at the ecological flow of a certain watercourse cross – section of a natural channel, which is a comparatively macroscopic physical variable, leading to two assumed preconditions; the first one is that the flow regime of natural channel belongs to uniform flow of open channel; the second is that the flow velocity adopts the average discharge of watercourse cross – section, in order to eliminate the impact of different velocity distribution to watercourse wetted perimeter.

#### 2.1.2 Principle

Based on the above two assumptions and the relational concepts, principle submitting EHRA to estimate instream ecological water requirement will be presented in the following.

According to the open channel uniform stream formula, the relationship among hydraulic radius

$R$ , average flow velocity of cross – section  $\bar{v}$ , hydraulic gradient  $J$  and roughness coefficient  $n$  can be obtained.

$$R = n^{3/2} \bar{v}^{-3/2} J^{-3/4} \quad (1)$$

where, the roughness coefficient  $n$  and the hydraulic gradient  $J$  are watercourse hydraulics parameter (namely watercourse information).

If the average flow velocity of cross – section is endowed with biological meaning, i. e., the aforementioned ecological flow velocity (as the flow velocity of fish migrating for propagation)  $v_{ecology}$  is treated as the average flow velocity of cross – section, the hydraulic radius possesses the ecological meaning (namely the EHR)  $R_{ecology}$ , then we can calculate the discharge of cross – section that satisfies the ecological water requirement for the maintenance of a certain ecological function of the river (such as the fish spawning migration).

### 2.1.3 EHRA and ecological flow determination

Taking the calculation of ecological water requirement that meet the requirement of aquatic biology and fish spawning migration as an example, the basic process to calculate watercourse ecological water requirement using EHRA are introduced.

Firstly, determine the flow velocity  $v_{ecology}$  that meet the requirement of aquatic biology (according to the living habit and breeding season of the fish as well as the river scale, it is generally 0.4 ~ 2.5 m/s). To figure out the ecological hydraulic radius  $R_{ecology}$  of watercourse across – section and then using  $R_{ecology}$  to calculate the cross – sectional flow area  $A$ . Secondly, obtain the relationship of  $A \sim R$  and calculate the ecological water requirement ( $Q_{ecology}$ ) of a certain watercourse cross – section in a certain time through the flow calculated by  $Q = n^{-1} R^{2/3} A J^{1/2}$ , namely the ecological flow containing aquatic biology and watercourse cross – section information, then determine migration period ( $T_{ecology}$ ) and calculate the ecological flow and runoff.

## 2.2 EHRA to estimate IFRTS

### 2.2.1 Confirm the permitting flow velocity

Permitting flow velocity is the flow velocity that would not erode or silt, that is to say, the flow velocity that would not erode or bring siltation to the river. For a certain section of the river, the flow corresponding to permitting flow velocity is the IFRTS within the watercourse. Permitting flow velocity  $v_c$  is within range of noneroding and non – silting velocity.

$$v_{min} < v_c < v_{max} \quad (2)$$

in which,  $v_c$  is permitting flow velocity;  $v_{max}$  is the noneroding velocity;  $v_{min}$  is non – silting velocity.

Permitting flow velocity is generally confirmed by the experiment.  $v_{max}$  depended on the soil quality of the riverbed, the soil types, grain size and compaction rate or the lining material of the channel and the flow within the channel, etc.  $v_{min}$  is determined by sediment concentration in the water, particle size of the sand and the water depth, it could also be calculated by empirical formula, namely:

$$v_{min} = \beta h_0^{0.64} \quad (3)$$

in which,  $h_0$  is the normal depth of the watercourse (the mean depth for the natural stream),  $m$ ;  $\beta$  is the siltation coefficient and is related to the sand – carrying condition of the stream.

When the current carried coarse sand,  $\beta = 0.60 \sim 0.70$ ; when it carried medium sand,  $\beta = 0.54 \sim 0.57$ ; when it carried fine sand,  $\beta = 0.39 \sim 0.41$ . The hydrologic stations in the water sources of the west line first – stage construction of South – North Water Transfer Project generally do not have the gradation materials of the silt, therefore, we could select  $\beta = 0.60$ . Based on formula (3), we could get the nonsilting velocity, since the permitting flow velocity is between the noneroding and non – silting velocity; we could select the peak value of non – silting velocity as permitting flow velocity, that is

$$v_c = \max \{ v_{min}^i \} \quad i = 1, 2, 3, \dots \quad (4)$$

### 2.2.2 Confirm of ecological hydraulic radius

Based on permitting flow velocity confirmed by the above steps, we could get ecological hydraulic radius that meet the non-eroding and non-silting demand of the river by formula  $R = n^{3/2} v_c^{3/2} J^{-3/4}$ , it is expressed by  $R_s$ , and then use the relation between ecological hydraulic radius and flow  $R_{ecology} \sim Q$  to estimate the ecological flow corresponding to ecological hydraulic radius.

## 3 Case study

The following case analysis over the computational process of using EHRA is to estimate instream ecological water requirement. Being the only hydrologic station in water transfer river Niqu River, Zhuba Station locates at 100°41'E, 31°26'N. The Zhuba Station, founded in 1959, has a catchment area of 6,860 km<sup>2</sup> and has survey data started from May 1960 (data on water level, flow, cross-section, etc.).

### 3.1 Selection of basic data

The basic parameters (including the calculation of  $A$ ,  $P$  as well as others) are necessary for applying EHRA to calculate instream ecological water requirement. Consequently, only fixed number of years possessing data on surveyed cross-section information, flow  $Q$ , water level  $Z$  are applicable for using this approach to calculate instream ecological water requirement. In this case, the 15 years data of Zhuba Station from 1972 ~ 1987 (excluding 1982 for lacking of actual surveyed cross-section information) are chosen to calculate the instream ecological water requirement of Zhuba Station each year, and the chosen data includes hydrologic data of actual surveyed cross-section information, mean monthly water level, monthly maximum water level, monthly lowest water level, mean monthly discharge, monthly maximum discharge, monthly minimum discharge, etc. This essay will take 1980 as an example to illuminate the process of applying EHRA to estimate instream ecological water requirement.

### 3.2 Calculation process

#### 3.2.1 Calculate EHR

According to the above-mentioned calculation procedures, we will firstly determine  $v_{ecology}$  which will satisfy the life and habitation requirement of the instream aquatic biology. According to the fieldwork and bibliographic information, the fishes in this river are primarily Schizotorax (Racoma), Nemachelus, and Euchiloglantis kishinouyei Kimura. Furthermore, the Niqu River belongs to a third-order branch of the Yalong River,  $v_{ecology}$  is 0.6 m/s. The watercourse roughness coefficient  $n$  is chosen as 0.031 and the watercourse hydraulic gradient  $J$  are taken as 4/1,000. The  $R_{ecology}$  of watercourse cross-section can be figured out as  $R_{ecology} = n^{3/2} v_{ecology}^{-3/2} J^{-3/4} = 0.9$  m.

#### 3.2.2 Determine the relationship between $q$ and $r$

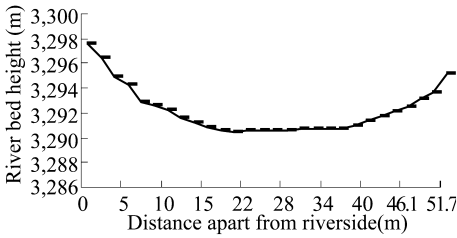
Utilizing actual surveyed cross-section information (actual surveyed cross-section of Niqu Zhuba Station in 1980 at Fig. 1), water level data, we could calculate the hydraulic radius of watercourse cross-section under different water level conditions (see Fig. 2).

According to the flow series (see Fig. 3) and aforementioned calculated hydraulic radius, we can calculate the relationship between  $Q$  and  $R$  (see Fig. 4).

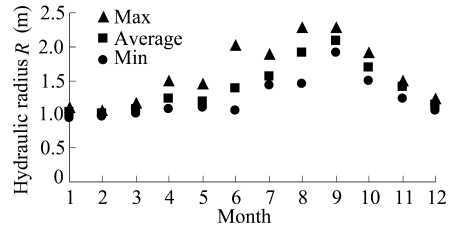
Utilizing power function to proceed matching, we can calculate the functional relationship between  $Q$  and  $R$ , i. e.  $Q = 16.774 R^{3.633,1}$ , and correlation coefficient is 0.99.

#### 3.2.3 Calculate ecological water requirement

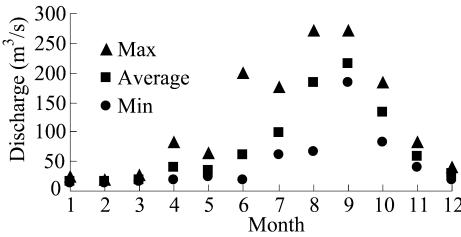
According to the calculated  $R_{ecology} = 0.9$  m, and  $Q = 16.774 R^{3.633,1}$ , we can get the ecological required water flow of Zhuba Station in 1980:



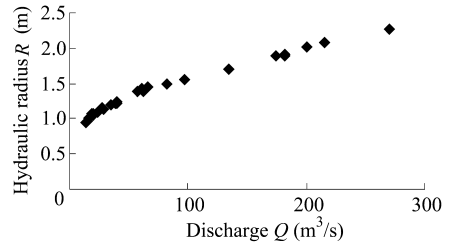
**Fig. 1** The surveyed Zhuba hydrological station cross – section of natural watercourse



**Fig. 2** Hydraulic radius of watercourse cross – section in Zhuba Station of Niqu (1980)



**Fig. 3** Flow in Zhuba Station of Niqu (1980)



**Fig. 4** Relationship between  $Q$  and  $R$  of Zhuba Hydrologic Station (1980)

$$Q_{\text{ecology}} = 16.774 \times 0.9^{3.633,1} = 11.44 (\text{m}^3/\text{s})$$

Utilizing the EHRA which is used for calculating the instream ecological water requirement mentioned in the above essay, we calculated each year ecological water requirement of Niqu Zhuba Station from 1972 to 1987 that may satisfy the living and habitation requirement of aquatic biology (see Table 1).

### 3.3 Discussion and analysis

To verify whether the calculation of EHRA confirms with the practical situation, we adopt Tennant approach to calculate the instream ecological water requirement of Zhuba Station synchronous with the time period of what EHRA has calculated.

According to the Tennant approach computing standard, the instream minimum ecological water requirement was calculated. During the general – purpose water usage period (from August to April of the next year), it takes 10% of the average monthly discharge for years as instream minimum ecological water requirement. During the fish spawning and rearing period (from May to July), it takes 30% of the average monthly discharge for years as instream minimum ecological water requirement. The instream favorable ecological water requirement was also calculated. During the general – purpose water usage period (from August to April of the next year), it takes 20% of the average monthly discharge for years as instream favorable ecological water requirement. During the fish spawning and rearing period (from May to July), it takes 40% of the average monthly discharge for years as instream favorable ecological water requirement. The results obtained by Tennant method are shown in Table 1.

As is shown in Table 1, basically the each year instream ecological water requirement of Zhuba Station (1972 ~ 1987) calculated by EHRA lies between the minimum and favorable amounts of ecological water requirement set by Tennant approach, among which, the ecological water requirement in 1973 calculated by EHRA is  $0.51 \text{ m}^3/\text{s}$  bigger than the favorable ecological water requirement calculated by Tennant approach; while the ecological water requirements of 1981 and 1985 are  $0.34 \text{ m}^3/\text{s}$  and  $1.34 \text{ m}^3/\text{s}$  respectively, smaller than the minimum ecological water requirement calculated by Tennant approach. Focusing primarily on the living habit of the local

aquatic creature and the climate features, the computing standard of Tennant approach in this essay is corresponding to local river ecological and environmental condition. In summary, the result of applying EHRA to calculate instream ecological water requirement has been verified by Tennant approach, while its quantitative estimates is more objective than Tennant approach and it avoids the artificial setting of the computing standard of Tennant approach.

**Table 1 The percentage of ecological flow occupying annual mean discharge in Zhuba Station**

Year	Average annual flow ( $\text{m}^3/\text{s}$ )	Ecological hydraulic radius approach		Tennant approach	
		Ecological flow ( $\text{m}^3/\text{s}$ )	Ecological flow /annual mean flow ( $\text{m}^3/\text{s}$ )	Ecological flow ( $\text{m}^3/\text{s}$ )	Ecological flow/annual mean flow (%)
1972	57.8	13.43	23.2	11.30 ~ 17.05	19.6 ~ 29.5
1973	43.5	12.48	28.7	7.57 ~ 11.91	17.4 ~ 27.4
1981	66.1	11.03	16.7	11.37 ~ 17.96	17.2 ~ 27.2
1983	54.5	11.70	21.5	10.13 ~ 15.55	18.6 ~ 28.5
1984	44.4	12.13	27.3	9.09 ~ 13.50	20.5 ~ 30.4
1985	77.4	12.18	15.7	13.52 ~ 21.22	17.5 ~ 27.4
1986	39.8	8.82	22.2	6.52 ~ 10.50	16.4 ~ 26.4
1987	54.4	14.76	27.1	9.53 ~ 14.93	17.5 ~ 27.5

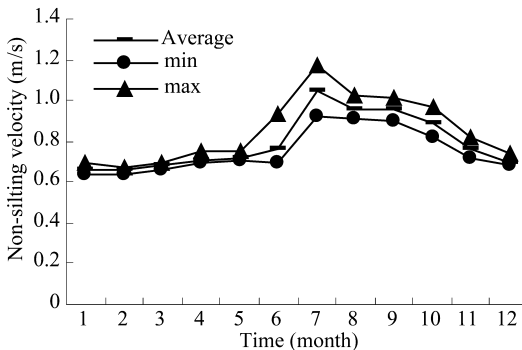
**Note:** The ecological flow is considered as the minimum flow for watercourse at non - flood season; because of space of a whole page limited, sect calculation result has been listed in Table 1.

## 4 Case study

The key to build EHRA is to confirm the ecological hydraulic radius, while the major factor to calculate ecological hydraulic radius is to calculate the ecological flow velocity, which is exactly the permitting flow velocity that would not erode or silt. The following part uses the calculation of IFRTS in 1987 of Daofu Station as an example to explain the computational processes of EHRA.

### 4.1 Calculate permitting flow velocity

Use the mean depth of the river,  $\beta$  value and formula (3) to calculate the changes of the non - silting velocity  $v_{\min}$  at Daofu Station within 1987 (Fig. 5).



**Fig. 5 Changes of non - silting velocity at Daofu Station within one year(1987)**

Select  $v_c = 1.16 \text{ m/s}$  as the permitting flow velocity of sediment transport during flood season based on the changes of non - silting velocity within the year in Fig. 5.

## 4.2 Calculate the ecological hydraulic radius of sediment transport $R_s$

Use  $R = n^{3/2} v_c^{3/2} J^{-3/4}$ , based on documentary, the watercourse roughness of Daofu Station is  $n = 0.031$ , the base slope gradient  $J = 8/10,000$ , and then the sediment transport ecological hydraulic radius is  $R_s = 0.031^{1.5} \times 1.16^{1.5} \times (8/10,000)^{-0.75} = 1.4$  m.

## 4.3 Calculate sediment transmission flow

Based on the relation between flow and hydraulic radius  $Q = 23.598 R^{3.406,5}$ ,  $r^2 = 0.988,3$  in Table 2, we could get the sediment transmission flow  $Q_s = 23.598 \times 1.4^{3.406,6} \text{ m}^3/\text{s}$  corresponding to sediment transmission hydraulic radius.

Use the above mentioned EHRA to estimate IFRTS of Daofu Station during flood season at the water sources of west line first – stage construction of South – North Water Transfer Project, the results are shown in Table 2.

**Table 2 IFRTS of Daofu Station**

Year	Average discharge from June to September ( $\text{m}^3/\text{s}$ )	Permitting flow velocity ( $\text{m/s}$ )	Sediment transmission ecological hydraulic radius (m)	Relation between flow and hydraulic radius	Hydraulic radius approach	
					IFRTS ( $\text{m}^3/\text{s}$ )	IFRTS/average discharge from June to September (%)
1966	273.00	1.18	1.47	$Q = 32.088 R^{2.809,9}$ , $r^2 = 0.987,7$	94.7	34.7
1967	154.75	1.13	1.37	$Q = 29.082 R^{3.100,1}$ , $r^2 = 0.989$	77.2	49.9
1968	261.75	1.21	1.54	$Q = 31.327 R^{2.921}$ , $r^2 = 0.994,3$	110.6	42.3
1980	293.75	1.19	1.49	$Q = 29.562 R^{3.007,2}$ , $r^2 = 0.982,9$	98.1	33.4
1982	329.25	1.23	1.57	$Q = 25.589 R^{3.155,4}$ , $r^2 = 0.979,6$	149.6	45.4
1983	203.75	1.19	1.50	$Q = 25.969 R^{3.245,6}$ , $r^2 = 0.979,7$	96.8	47.5
1984	226.75	1.29	1.7	$Q = 24.276 R^{3.177}$ , $r^2 = 0.971,4$	121.4	53.5
1985	390.75	1.34	1.78	$Q = 22.896 R^{3.195,2}$ , $r^2 = 0.969,2$	144.5	37.0
1986	150.45	1.08	1.28	$Q = 24.073 R^{3.515,9}$ , $r^2 = 0.974,2$	57.3	38.1
1987	271.25	1.17	1.46	$Q = 23.598 R^{3.406,6}$ , $r^2 = 0.988,3$	85.7	31.6
Average					100.2	

**Note:** because of limited space of a whole page, only part of the calculation results are of the listed in Table 2.

It is observed from the computational solution of Table. 2 that the IFRTS of Daofu Station during flood season calculated by EHRA occupies about 29.7% ~ 59.5% of the average discharge during flood season, the mean value of sediment transmission flow from 1966 to 1987 is 100.2  $\text{m}^3/\text{s}$ , and the IFRTS calculated by sediment transmission water flow concept is 90  $\text{m}^3/\text{s}$ , these two figures are similar. It is obvious that using ecological hydraulic radius to estimate the IFRTS during the flood season is feasible.

## 5 Conclusions

Based on the characteristics of river ecological water requirement and the requirement of fixed parameter, the EHRA, which has considered the watercourse information (including hydraulic radius, roughness coefficient and hydraulic gradient) and the required flow velocity necessary for the maintenance of river ecological function, has been proposed. The instream ecological water requirement during a certain period of time of the river course can be determined by checking  $Q$  from the relation curve between  $Q$  and  $R$  at the fixed  $R_{ecology}$ .

It has used the newly proposed EHRA to carry out the estimation of 15 years annual ecological

flow of Zhuba Station at Niqu Branch of Yalong River from 1972 to 1987 (excluding 1982). The results show that the Zhuba Station ecological flow calculated by EHRA lies between the minimum and favorable ecological water requirement set by Tennant approach. The main reason is that it has considered the requirement of fish towards the flow velocity, so the result is corresponding to the practical situation of the planned Western Line of the South – to – north Water Transfer region. EHRA is the integration of hydrology (including the information on cross – section, flow, water level, etc.) and hydraulics (Manning formula), so it avoids the uncertainty of wetted perimeter approach caused by defining critical point.

Meanwhile, by confirming permitting flow velocity  $v_c$  and sediment transmission ecological hydraulic radius  $R_s$ , we built the EHRA to calculate IFRTS, also calculated the IFRTS during the flood season at Daofu Station of the years with sedimentary data (1966 ~ 1987, exclude 1969, 1970 and 1981), the calculation shows that the IFRTS calculated by EHRA of Daofu Station during the flood season occupies about 29.7% ~ 59.5% of the average discharge during the flood season, the sediment transport flow mean value from 1966 ~ 1987 is  $100.2 \text{ m}^3/\text{s}$ , which is close to the IFRTS  $90 \text{ m}^3/\text{s}$  calculated by IFRTS concept, this shows that using ecological hydraulic radius method to calculate IFRTS is feasible. It provided a new method to estimate IFRTS.

The new approach proposed is not only applicable for the analysis of flow velocity suitable for aquatic systems such as fish habitat, and the water flow velocity of sediment transport water requirement, but also available to determine refined cleansing water required for diluting contamination, which is the extrusive characteristic of the EHRA.

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## Constructing the Modern Dujiangyan Irrigation System in Shandong for the Benefits to River Harness, Grand Canal Recovery and Optimization of Water Resources on the Huang – huai Plain

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**Abstract:** The harnessing of Yellow River has always been the focus of the state. Now the state has decided to implement the project of “introducing water from South to North”, so it is very important to do research on the combination of this project with the treatment of Yellow River and Huaihe River, so as to realize the optimized deployment of the water resources in the Huang – huai Plain. The theoretical research of this topic has lagged behind the practical need now. Presently it can be said that the problems in the project of “introducing water from South to North”, the problem of drought in the south of Huang – huai Plain and flooding in its north, and the problem of ecological disequilibrium.

Having been working on the decision making research concerning the Yellow River and the water resources, the author thinks that now it is time to treat the Yellow River by summarizing the former experience of Yellow River harnessing in the past and working out the feasible harnessing strategy accordingly. The lessons learned from the former Yellow River harnessing experience is that the Yellow River has been isolated and Shandong has been separated in the lower reach of the Yellow River, the flood control tactics of “comprehensively planning and combining together the methods of storage and diversion” hasn’t been realized, which has in turn caused the ecological disequilibrium.

The major problem of Yellow River is that there are too few water yet too much sediment, which caused the disequilibrium between the water and sediment. The method to solve it is to increase the water supply and reduce the sediment. The focus shall be put on the increasing of water in the two ends of the river and reduce the sediment in the middle reach. In the upper reach if the water of Tibet can be introduced into the Yellow, the potential of water increase will reach hundreds of billions cubic meters; in the lower reach if the water can be introduced from Henan and Shandong into the Yellow River, the potential of water increase will reach about ten billions. The most efficient and rational method to increase water in the lower reach is to construct the present Dujiangyan water hub in Shandong province, which should be listed as the No. 1 project of the Ministry of the Water Resources.

**Key words:** the Modern Dujiangyan Irrigation System, river Harness, grand canal recovery, optimization of water resources, the Huang – Huai Plain

The Yellow River (Huanghe), the well – known cradle of Chinese Civilization, however, has also been a great concern over long historical time due to frequent catastrophic floods, and the harness of the Yellow River has always been an important task to the nation. China has the long history and excellent tradition in river harnessing at the splendid periods of dynasties in history, such as Han Dynasty, Tang Dynasty and Qing Dynasty. Presently, China has entered a new splendid and blooming period under the leadership of the Communist Party of China (CPC). A strategic decision on the South – North Water Diversion Project has been made, however, an important problem has been raised to the governors of water conservancy departments and hydrologists: How to combine the South – North Water Diversion Project with the harness actions on

the Yellow River and Huai River in order to optimally allocate the water resources on the Huang – Huai Plain? Undoubtedly, the theoretical research on this matter has lagged behind the practices. And several key issues such as problems in South – North Water Diversion Project, patterns of South – Flood – North – Drought in the Huang – Huai Plain and unbalance of ecosystem are essentially related to this matter.

Supported by the CPC of Shandong Province, Shandong Government, Ministry of Water Resources and Yellow River Conservancy Commission (YRCC), I has dedicated to the research of decision making on the Yellow River and its water issues from 1986 when I came to work in Dongying City, Shandong Province. Since then I have also completed several key research projects as person in charge (e. g. , State Key Project of China within the 8th 5 – year Plan, Provincial Key Project of Shandong within 10th 5 – year Plan) that are evaluated as internationally outstanding contributions on the harness of the Yellow River. Based on these works, I will present some viewpoints on the harnesses of the Yellow River and Huai River and the water issues within the Huang – Huai Fluvial Plain.

Essentially speaking, we should take full advantage of the Nansihu Lake and construct the modern Dujiangyan Irrigation System by seizing the rare historical opportunity of South – North Water Diversion Project so that we could control the floods in Huang – Huai Plain, recover the navigation of the Jing – Hang Grand Canal and improve and optimize the ecosystem in the Huang – Huai Plain. These effective measures would promote the development of national water conservancy and be beneficial to the Peaceful Rise of China in the new century.

## **1 The time is ripe for the essential harness of the Yellow River**

The Huang – Huai Plain, constructed by alluvial deposits of the Yellow River during the geological time, has been and presently is dominated by the Yellow River. Essential harness of the Yellow River will promote the controls of floods within the Huang – Huai Plain. It is the right time for the essential harness of the Yellow River.

### **1.1 Brilliant achievements on the harness of the Yellow River during the past 60 years**

During the past 60 years many effective practices including water storage in upper reaches and flood discharge in the lower reaches, dam constructions, water irrigation systems and protections in the estuary, as well as the dam groups with total capacity of 57.5 km<sup>3</sup> (Xiaolangdi as a representative) has predominantly controlled the previously frequent floods, stabilized the estuary and constrained the lower channel. The Yellow River has presently been the major linkage in the economic development of the Northern China, irrigated cultivated land of more than 2.0 million ha in Shandong Province. It provides water not only to the cities along the river, but also to the cities outside of the river basin such as Qingdao, Tainjin, Baiyangdian and even to Yantai and Weihai in the near future.

### **1.2 Theoretical breakthrough in the harness of the Yellow River**

The Yellow River is the mother river of China, but also the great concern of the nation. And thus the harness of the Yellow River was the first major task for all the dynasties. The harness of the Yellow River during the history reflected the outstanding scientific achievements in the subject of water conservancy. By the Ming Dynasty the theory of harness of the Yellow River had been systematic, as indicated by the monograph by Pan Jixun, a famous experts in Ming Dynasty. Particularly, the Chinese people have obtained great achievement on the harness of the Yellow River including both the fundamental research and engineering practices. The difficult problems unsolved over the long time such as stabilization of the estuary and constraint of the lower channel, have been solved both theoretically and practically. A set of countermeasures summarized as flow diversion, dredging; utilization of tides and discharging into the sea in stable direction have been proved to be

effective; and the engineering arrangement has passed the national appraisal which has the idea of one main – one auxiliary river course and making the river stable by these two river courses. Based on these practices a three – constraints theory was developed, and a new idea was proposed that emphasizes the contributions of marine dynamics to riverine sediment transport. All these achievements provide theoretical support to the harness of the Yellow River.

### **1.3 China has the strong power to harness the Yellow River**

The harness of the Yellow River has become the major task in the national water conservancy. The administrative departments and the local provinces along the river should make full preparations from both theory and practices so that we can seize the opportunity of South – North Water Diversion Project and promote the harness of the Yellow River to a new level.

### **1.4 President Hu Jintao and Premier Wen Jiabao congratulated the 60th anniversary of the Harness of the Yellow River, and called for further and better achievements in the harness of the Yellow River**

Both the top leaders emphasized the new idea of harmonic relationship between human and nature, which presented the new direction of the harness of the Yellow River in the new century. Under such circumstance, it is of priority to proposed initiative of river harness in the new century under the guidance of concept of scientific development.

## **2 To review the experiences and lessons and constitute the guideline of river harness based on the fact of the Yellow River**

We should acknowledge our achievements in the harness of the Yellow River; on the other hand, we also should consider the mistakes that will be beneficial for our further progress, such that;

### **2.1 The most valuable lesson is the isolation of the Yellow River in the lower reaches and the separation of Shandong from the Yellow River**

In the 1950s the experts from the former Union of Soviet Socialist Republics (USSR) gave wrong guidance, leading to mistakes and failure of the Weishan Project, causing the reality of isolation of Yellow River and separation of Shandong over a long period. On the other hand, the overall plans that made by Premier Zhou Enlai was not carried out deeply, which did not allocate the water resources in the Huang – Huai Plain in an optimized way. The Yellow River lost its dominance in the Huang – Huai Plain when it was isolated; and the Shandong Province lost its dominance in water resources when the Shandong is separated, leading to the unbalance between water and sediment and more serious deposition and more dangerous suspended riverbed in the lower channel. Meanwhile, drainage area of the Huaihe River was expanded and water discharge increased, aggravating the floods in Huaihe River and leading to more troubles in the harness of the Huaihe River.

The Grand Canal has been abandoned for long time, and the Shandong Province was divided geographically by the Yellow River, Huaihe River and Haihe River. Such reasonless division destroyed the predominance of water resources in Shandong Province, resulting in the floods in the southern Huang – Huai Plain and serious droughts in the northern part. The improper way of water allocation in the Huang – Huai Plain caused the water shortage in Beijing and Tianjin and consequent deterioration of ecosystem. The primary causes are the mistakes of the Weishan Project;

(1) The Weishan Project segmented the Yellow River, increased the channel deposition in the lower reaches and raised the riverbed. The project was completed in 1961; however, it was destroyed in 1963 owing to its negative effects. Because of the subtle relationship between China and

the former USSR and subsequent Culture Revolution, these mistakes were not corrected and well studied by the administrative departments and thus left serious future disasters that endangered the Yellow River and Shandong;

(2) The Weishan Project destroyed the Daicun – Nanwang System. The wrong design of Weishan Project by the experts from former USSR changed the south – north diversion of floods into the unidirectional southern diversion, which disabled the Daicun Dam – Nanwang Water Diversion Sluice (Daicun – Nanwang System) that was similar to the famous Dujiangyan Irrigation System;

(3) The Weishan Project caused the failure of recovery of the Grand Canal, prolonged the time without navigation. At the early of People's Republic of China an expected function of the Weishan Project was to recover the navigation of the Grand Canal by the cross of the Yellow River and the Grand Canal. However, this plan was aborted because of serious siltation in the Grand Canal by the heavy sediment from the Yellow River. Such tentative plan was firstly initiated by the people in Song Dynasty and applied for many times in the following time, but all these actions failed. We should learn the lesson from this.

(4) The Weishan Project enhanced the floods in the western Shandong Province. The floods diversion in the cities of Heze and Jining was unidirectional southward by the Weishan Project instead of the previous south – north way. Thus the increase in water level of the Nansihu Lake enhanced the floods, which endangered the 16 million people within the two cities and hence became a negative factor to the social and economic development in the western Shandong.

(5) The Weishan Project decreased the drainage area in the lower reaches as well as the water discharge into the main stream of Yellow River, increasing the sediment concentration and raising the riverbed in the lower reaches by rapid deposition.

(6) The Weishan Project increased the drainage area of the Huaihe River, correspondingly increasing the floods of the Huaihe River and causing more troubles for the harness.

All the mistakes mentioned above led to the isolation of Shandong by three river basins, destroyed the predominance of water resources in Shandong; at the same time, the Yellow River lost its dominance in the Huang – Huai Plain which directly caused the deterioration of ecosystem in the Huang – Huai Plain, particularly in the Northern China Plain.

Historically, the Yellow River was dominant in the Huang – Huai Plain and the Huaihe River was its tributary for either southern shift or northern shift of the Yellow River course. The problem that how to keep the dominance of the Yellow River in the Huang – Huai Plain has been a major task to the administrators and hydrologists along with long – term stabilization of the Yellow River course. We should pay much more attentions to this issue with insightful research and scientific decision. During the past 60 years we have acquired a lot of experience for this problem. In order to recover and develop the dominance of the Yellow River in the Huang – Huai Plain we must correct the mistakes of Weishan Project and take full advantage of the Nansihu Lake that should be merged to the Yellow River basin and flow northwards.

## 2.2 To make decision based on the fact of the Yellow River

The Yellow River is characterized by less water and more sediment, different sources for water and sediment and unbalance between water and sediment. An effective way to overcome such disadvantage is to increase water discharge in the upper and lower reaches and to decrease the sediment yield in the middle reaches. Water increase is dominant to the success of the essential harness of the Yellow River and the decrease in sediment yield is a critical measure to ensure the effective harness of the river.

Increase of water discharge should be focusing on the upper reaches (Qinghai – Tibet Plateau) and lower reaches (Henan and Shandong Provinces). It is estimated that the potential water increase in Henan and Shandong Provinces, approximately 20 km<sup>3</sup>, would be greatly beneficial to the harness of the Yellow River, recovery of the Grand Canal, reduction of riverbed in the lower reaches and optimization of the ecosystem in the Huang – Huai Plain.

The potential water increase in Qinghai – Tibet Plateau is striking. In last September I made a

special trip to Tibet Auto – administration Region to survey the local water resources. As from the local historical records I noticed that the total water resources in Tibet is  $600 \text{ km}^3$ , among which only 1% is used domestically. This means that the potential water increase to the Yellow River is at least  $100 \text{ km}^3$ . The the Yarlung Zangbo River (Brahmaputra) discharges water outside of China is about  $165 \text{ km}^3/\text{year}$ , one third of which ( $53 \text{ km}^3$ ) is equivalent to the water discharge of the Yellow River. Therefore, increase the water of the Yellow River from the Tibet is a strategic measure to the harness of the Yellow River, mitigation of water shortage in the Northern China and related ecological issues.

From the political view linkage of water between Tibet and the Yellow River is a strategic measure for elimination of the Independence of Tibet. The facts worldwide proved that the geographical linkage could establish and promote the nation complex. The three major Chinese rivers (Yangtze, Yellow and Pearl) flow eastwards to the sea together with the Grand Canal linking the South China (Hangzhou) to North China (Beijing). The crossing river system of China generated the economic bloom from south to north along the coast, consequently resulting in the base of ethnic harmony and state unification. In this framework a large part of the Tibet would be a part of the Yellow River drainage basin, and highway between Tibet and Qinghai would be expected to enhance the linkage between Tibet and Qinghai Province.

As for the transfer of Tibet water into the Yellow River, there are two essentially similar plans: Little West Route proposed by Yellow River Conservancy Commission (YRCC) and Large West Route proposed by nongovernmental association. I surveyed the Large West Route in Tibet in last year and subsequently debriefed the introduction of the Little West Route from YRCC in Zhengzhou. The plan seemed to be quite sophisticated, and the state should start this project as soon as possible. This would be the No. 1 project for the Ministry of Water Resources.

### **3 To construct the modern Dujiangyan Irrigation System and to gain the breakthrough in scientific harness of the Yellow River**

I studied the Dujiangyan Irrigation System, Sichuan, and the results were shown in one of my paper titled as “Principle of the Dujiangyan Irrigation System and the Harness of the Lower Yellow River”. On the international conference of 2,260th anniversary for the Dujiangyan Irrigation System in 2004 my paper was listed in the conference symposium, several national academicians of CAS enjoyed my research and told me: “Your suggestion is very good, but it should be initiated from top level!” Here, we should discuss the advantages of the modern Dujiangyan Irrigation System in Shandong as follows:

#### **3.1 We must fully understand the naturally geographical settings characterized by the Mountain Tai, the Yellow River and the Nansihu Lake and the hydrological environment, which is the basic condition for the construction of the modern Dujiangyan Irrigation System in Shandong**

Over the long historical period from Sui & Tang Dynasty to early Ming Dynasty (589 ~ 1411 AD), many wise governors and hydrologists paid many attentions to such geographical settings and predominance in water resources. The heart of the Grand Canal composed by Jinkou Dam, Gangcheng Dam and Daicun – Nanwang System has been built based on 1,000 – year efforts. These hydraulic facilities can transfer water from the Wenhe River to the Grand Canal and make the Grand Canal flowing smoothly across the topographical ridge in Shandong. At present if the Jiliang Canal on the East Route of the South – North Water Diversion Project were treated properly and the wrong plan for the 3rd grade water – lift works were corrected, the navigation of the Grand Canal would recover soon and the aims of water increase in the Yellow River, disaster control in the Huaihe River and construction the modern Dujiangyan Irrigation System would thus be realized.

### **3.2 We must fully understand the strategic significance of Nansihu Lake, which is critical to the construction of the modern Dujiangyan Irrigation System in Shandong**

Nansihu Lake is the key factor to the scientific design of East Route of the South – North Water Diversion Project and the construction of the modern Dujiangyan Irrigation System in Shandong. The lake has a total area of 1,268 km<sup>2</sup> with dam – top elevation of 39.5 m. The bottom elevation of the lake is approximately 30 ~ 32 m with a safe elevation of 36.2 m and normal elevation of 34.2 m. There are totally 53 rivers discharging water into the lake with a drainage area of  $31 \times 10^3$  km<sup>2</sup> and regulation storage capacity of 7 km<sup>3</sup> estimated from the safe elevation of 36.2 m. Since the People's Republic of China the mean annual water discharging southward was 2.5 km<sup>3</sup>/year with maximum discharge of 9.3 km<sup>3</sup>/year. Therefore, there are plenty of water resources in Nansihu Lake that we can use. We can link the Nansihu Lake with the Lunan Canal (total length of 193 km and fall of elevation of 29 m). Under such circumstance, additional water of 3.27 km<sup>3</sup> would be flow into the Nansihu Lake from the drainage basin of  $23 \times 10^3$  km<sup>2</sup>. Therefore, the potential water resources that can be diverted from Nansihu Lake would be approximately 5 km<sup>3</sup>.

### **3.3 We must learn the historical lessons from the Daicun – Nanwang System, which is the theoretical basis to the construction of the modern Dujiangyan Irrigation System in Shandong**

In the early Ming Dynasty the officer in charge of water affairs Song Li and the expert Bai Ying constructed the Xiaowenhe River at the elevation of 50 m from the Dawenhe River and a water diversion sluice at elevation of 39.5 m based on the survey of the Grand Canal and topographical ridge (Nanwang country) of Shandong conducted by Guo Shoujing, an expert in Yuan Dynasty. These facilities diverted water from the Dawenhe River to the Grand Canal and supported the navigation of the Grand Canal for nearly 500 years (1141 ~ 1902 AD) from Ming Dynasty to Qing Dynasty. These works greatly promoted the development of water conservancy and river navigation in China, and were recognized as the ancient Dujiangyang Irrigation System in Shandong. However, these facilities were destroyed in the 1950s when the Weishan Project was constructed. A group of ancient architectures that commemorated the effective diversion works were also destroyed, however, the state planned to rebuilt at present.

We can find that the dam – top level of the Nansihu Lake (39.5 m) is almost same as the ground elevation of the Nawang Country. Therefore, the Nansihu Lake can divert water instead of the Nanwang water diversion sluice. The Nansihu Lake with total 53 rivers draining and a area of  $31.3 \times 10^3$  km<sup>2</sup> is much more effective in water diversion when compared to the Nanwang Water Diversion Sluice that has only one river (Dawenhe River) and a drainage area of  $9.8 \times 10^3$  km<sup>2</sup>. The efficiency of water diversion by the Nansihu Lake will increase by 5 times of that by Nawang Water Diversion Sluice so that the navigational demand of the Grand Canal will be satisfied.

### **3.4 To construct the modern Dujiangyan Irrigation System**

The detailed plan for the construction the modern Dujiangyan Irrigation System is as follows:

#### **3.4.1 To reinforce the Nansihu Lake and to divert water southwards and northwards, particularly northwards**

The water elevation of the Nansihu Lake should be controlled below 36.2 m and the water is diverted northwards when the southward navigation was guaranteed. When the water elevation is high above 36.2m the water will overflow southwards to discharge the floods; otherwise, the water is diverted northwards to supply water to the Grand Canal.

#### **3.4.2 To decrease the riverbed elevation and remove the water gates**

The 3rd grade water – lift works and 3rd grade ship locks should be removed from the Jiliang

Canal, as well as 27 flood relief stations. If we excavate the volume of  $6,850 \times 10^4 \text{ m}^3$  by the size of 30 m at the south outlet and 28 m at the north outlet with width of 70 m, we will create a large plain reservoir linking with the Nansihu Lake and the Yellow River. Therefore, we can get a natural waterway by constructing a tunnel through the Yellow River, which will be beneficial to the navigation north to Jining and floods control in the west of Shandong.

### 3.4.3 To construct tunnel through the Yellow River

At the cross of the Yellow River and the Grand Canal, a 10 meter high tunnel through the Yellow River can be designed with the bottom elevation of 28m. At this place the bed elevation of the Yellow River is 42 m with 4 m thick protective layer above the tunnel. The width of the Yellow River there is 3,100 m. Four culverts are designed for this tunnel, of which the middle two ones are 25 m wide for ship navigation and the other two on both sides are of 8 ~ 10 m in width for car traffic. Therefore, the tunnel is multi-functional for river flow, navigation, car traffic, flood control and irrigation, which would have been the world miracle of hydraulic engineering.

This tunnel will facilitate the water flowing northwards into the Grand Canal and the recovery of the navigation of the Grand Canal. Under such circumstance, the ecosystem in the North China Plain, particularly in the Beijing and Tianjin will be optimized. In addition, if a conductive channel is constructed linking the north bank of the Yellow River and Jinan, the water increase is estimated to be  $2 \text{ km}^3/\text{year}$ , and the lower Yellow River channel below Aishan (373 km long and 500 m wide) would be eroded and the bed elevation would be decreased by 0.1 m. Such results agree with the effects the Water – Sediment Regulation Scheme by the YRCC since 2002.

Comprehensively, the combination of Nansihu Lake, Jiliang Canal and the tunnel through the Yellow River will result in self-flow, self-regulation and self-control of the water; the water in the lakes will be used northward, and will be filled up by the Yangze River; and long way transfer will be divided into short distance delivery. The system which has the advantages of stable flow across rivers, mutual benefit, and self-settling of the problems will be established. And therefore the modern Dujiangyan Irrigation System in Shandong would come into being. The ancient Dujiangyan Irrigation System in Sichuan regulated the Minjiang River and irrigated the Chengdu Plain, as recognized as a miracle of the world hydraulic engineering; while the modern Dujiangyan Irrigation system in Shandong will regulate the Grand Canal, the Yellow River and the Huaihe River, irrigate the Huang – Huai Plain, control the floods/drought in the plain and optimize the ecosystem, which would be another miracle of the modern Chinese hydraulic engineering.

## 4 To combine the South – North Water Diversion Project with the harness of the Yellow River is the only way for the benefit of the South – North Water Diversion Project, essential harness of the Yellow River and ecosystem optimization in the Huang – Huai Plain

The South – North Water Diversion Project has three routes: West Route, Middle Route and East Route, among which the Middle Route and the East Route are not related to the Yellow River. Such a design is not in accordance with the policy made by the Central Committee of CPC and the Government that emphasized the comprehensive functions of the big project. And the separation of Shandong that was initiated in the 1950s will continue, which will reduce the benefits of the South – North Water Diversion Project and retard the progress of the harness of the Yellow River. In fact, the combination of East Route of South – North Water Diversion Project with navigational recovery of the Grand Canal and harnesses of the Yellow River and the Huaihe River, as well as the combination of West – East Water Diversion Plan in Shandong with navigational recovery of Xiaqinghe River, should be the expected benefit from the South – North Water Diversion Project, which should be the fundamental of this project. The means of such combinations include:

—The East Route plan should be combined with the construction of the modern Dujiangyan Irrigation System in Shandong and the water from the Huaihe River should be diverted to the Yellow River. This is the new development and application of the original idea of ‘eroding the Yellow River

with the water from the Huaihe River' proposed by Pan Jixun in Ming Dynasty;

—As for the Middle Route, an overflow sluice should be built at Zhengzhou so that the water from the Hanjiang River will be diverted to the Yellow River. This is also the last wish of the former director of YRCC;

—The plan of West Route should start as soon as possible, as the water diversion (approximately 100 km<sup>3</sup> from the long run) from the Tibet is taken into account, so that the harness of the Yellow River and water tension in the North China will be relaxed. This would be the major target of water conservancy for the Peaceful Rise of China in the new century.

## **5 To modify the Zhoushangyong Canal and divert the intercepted floods northwards**

During the Great Leap in 1958 the people in Henan Province built the Zhoushangyong Canal that is of important scientific value. The Zhoushangyong Canal can be modified into an important river for flood diversion that will divert the floods in Henan northwards, mitigate the pressure of floods in Anhui Province and relax the water tension in the North China. The detailed plans are as follows: extending the canal upstream to Luohe City of Henan at elevation of 65 m and extending the canal downstream across the Yellow River and linking the canal with the Tuhai River, Majia River and Zhangwexin River. Therefore, we can construct a river for flood diversion from south to north on the Huang - Huai Plain with tentatively designed flow discharge of 1,500 m<sup>3</sup>/s. Under such circumstance the floods in Anhui and water tension in North of China will be controlled since the floods can be diverted southwards into the Yangtze River, eastwards into the sea and northwards into the Yellow River. It is hard to mitigate the floods in Anhui by the means of diverting the floods in Jiangsu Province southwards and eastwards. Our suggestion should be the best way to mitigate the floods in Anhui Province and to relax the water tension in North of China, and we should make further research on this effective plan.



# The Application and Popularization of Electricity Technology of Detection in Yellow River Dike

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**Abstract:** In allusion to the fact of much hidden dangers and bad quality of Yellow River dike, YRCC took full advantage of technical research fruit of eighth – five plan and national ninth – five important popularization program of electricity detection technology to organize some departments to carry out the application in lower Yellow River dike. The detection research outcome provided decision – making foundation for dike embankment and flood controlling and obtained remarkable economic and social effect. At same time this paper puts forward popularization proposal in future by electricity detection methods in dike management.

**Key words:** detection technology, popularization measures, estimation effect Perspective of application

## 1 Outline

### 1.1 Necessity of hidden dangers detection in Yellow River dike

Hidden dangers in dike means various elements that endanger dike, such as fissures, holes, loose earth, soft layers and leakage cavity which cause by nature and human influences. Yellow River dikes were built on basis of historical embankment and non – governmental levees after many times reinforcement. Because of complex of historical status, the dike quality is different in many aspects and formed the trait of caves, fissures and incompact earth. The modern history of Yellow River harness indicates that the main reasons of river breaches were mostly caused by hidden danger elements inside dike except for some causation of flood inundation of overflow and river trends scour. Dike engineering is important material basis of Yellow River flood control. Quality inside dike and actual capability of flood control is directly related to Yellow River flood control safety and this is the crucial technology problem of dike safety management. Therefore, it is necessary to select advanced detection instruments and popularize new detective technology to judge the hidden dangers rapidly and exactly.

### 1.2 Technical characteristics of dike hidden danger detection by electricity

Theoretically speaking, the detection methods maybe divided into three ones that is electricity, magnetic and Rayleigh Wave. As to different hidden dangers, there are advantage and disadvantage for these three methods. It can get the best effect to use AD resistance method to detect dike body on transverse fissures, holes and loose earth.

Discharging method, nature electromagnetic method and motivated polar method is useful in detecting seepage line and piping instance. Magnetic methods maybe divided into instant magnetic and pulse geographic radar one. The theory of instant magnetic method is to use second electromagnet attenuation characteristics to determine hidden dangers trait. For nonce, instant magnetic method is only used to detect fissures, holes and loose earth layers or the weak points in historical basis. Pulse geographic radar method detects shallow depth in sandy soil, and it can easily find holes, loose earth layers and historical breaches site. Rayleigh Wave method judges dike solidity and its soft earth layer distribution by relations of transverse wave rate and cut modulus with transverse rate of elasticity wave non – even trait in spread.

At present, it mainly uses electricity method to detect hidden dangers inside dike. It is easy to

master this method conveniently. Electricity method is simple and practical and spends less time to be trained, in addition, the price of it is lower and popularized easily and economically.

The popularization of instant magnetic method is lower. It is used only in few departments and needs operators to master relative knowledge of magnetic. The detection was adopted with non – loop and can detect continuously. Its detecting rate is rapid, but the detected data was difficult to explain. Non – professional people cannot be competent for this work. Pulse geographic radar method detection can get well effect in detecting holes and loose earth layers, but is not evident in detecting single fissure inside dike.

Above all, Electricity method has economical, rapid and lower cost trait in detection, therefore, it can use this method to widely probe hidden dangers and determine the location and depth of them. If it needs to further ascertain character of it, we should use high – dense electricity method combined with other ones to detect in detail. In short period, it can rapidly get to purpose of detection of hidden dangers.

## **2 Application and popularization of electricity method in detection of hidden dangers**

### **2.1 Plan of application and popularization**

#### **2.1.1 Technical route**

To compare and select advanced detecting instruments and determine the type of instruments and enhance the improvement of them, and to prompt the regulation of detection work, according to principle of first key point and later average in detection in detail on large scale, thus ascertain the hidden dangers situation.

First of all, we investigate and select type of instrument and improve the selected one, then applying in practice, further we stipulate the detection rules in order to regulate detection work.

Secondly, we will detect overall the Yellow River dikes. For the discovered very important hidden danger points, we will detect them once in detail. Combined with reinforcement of dike embankment, we set priority of them to eliminate these hidden danger points in order to enhance the capability of flood control.

#### **2.1.2 Plan of popularization**

The first step is selecting suitable instrument of Yellow River dike hidden danger detection on basis of investigation of instrument in our country. During this period, we mainly adopt the measures of practical test, grouting test and digging test, and finish the popularization of 20 km.

The second step is to put fourth improvement proposal according to discovered problems and improve the selected instrument. At same time, we stipulate the management regulations to standardize the detection works.

The third step is popularization stage. We will detect all dikes in lower Yellow River once, and make ascertain real situation of dikes, set up technical files, this will provide foundation for dike embankment and water project management.

### **2.2 Organization of the detection**

In order to get effective outcome of application of hidden dangers detection, we set up a leading group which is formed by river affairs department of YRCC, department of international cooperation, science and technology of YRCC, department of planning and programming, finance department of YRCC, Shandong Yellow River bureau, Henan Yellow River bureau as well as detection brigade of YRCC.

All people from provincial bureau formed detection working group. They distribute stage task to individual and specify the responsibility, and gradually carry it out on schedule.

## 2.3 Measures of guarantee

### 2.3.1 Technical guarantee

(1) Technology priority. The hidden dangers detection technology is accomplishment of eighth – five plan of YRCC. This research production was appraised as international advanced technology by water resources ministry. In Aug. 1997, it was planed as popularized program by science and technology ministry of our country. After many years of improvement, the detection technology has got to new high level.

(2) Intellectual priority. Some professionals who grasp this technology consist of a working group. Meanwhile, the members of this group are from YRCC, they are familiar with Yellow River dike situation, and they directly participate in application, it is convenient for them to coordinate relations and raise the operators work level.

(3) Instrument priority. Whether the practical use or technology trait, the selected instruments are all advanced in our country. In July 2000, national flood control office organize 20 kinds of detecting instruments to be compared among them, the instrument made by YRCC was appraised as first grade by appraisal experts.

### 2.3.2 Quality measures of guarantee

During detection, we stipulated strict safety regulations. They include veracity of measures and precision of detection.

(1) Orientation precision of measure. It regulates that use measure rope to locate measuring line. The measure work starts from zero KM point and end till to the nest KM sign.

You should take down the actual length of measuring rope and write down the rope distance at 100 m sign in order to ensure the same detection site using other detection methods in future.

We select fixed 100 m or 1,000 m sign as location foundation, so that we have the pertinence and veracity for dike embankment and flood control scheme stipulation. Thus, it is convenient to compare with other data when we lay out the project construction plan.

(2) Precision of hidden dangers detection. Before implement of detection, we should proofread the consistency of the instrument, if the proofread is ok, it may be used in detection. If the circuit is not well you should enlarge the voltage and repeat the data. If the data cannot be read stably, you should improve the circuit till get the reliable data read. When the data read increases or reduces abruptly you should repeat the measures and check the electricity leakage now and then. After daytime task, you should connect the read data to computer by instrument component RS232, and the data are delivered to computer, combined with resistance. If finding any problems, you should repeat detection in time. The outdoors work should be followed at any moment in order to ensure the detection quality.

## 2.4 Application and popularization of hidden danger detecting methods by electricity

In 1995, after overall investigation, internet index and recommendation of water resources ministry, we compared national and international instruments of detection and selected three kinds of instruments made respectively by Yellow River design Co. , Shandong Yellow River bureau and Jiujiang water research institute of Jiangxi province as alternative. These three kinds of instruments were all adopted electricity method and their operation theory was same. In May 1996, these three instruments were tested in Dongpinghu lake dike, Changyuan county Yellow River dike and new left dike of Qin river in Wuzhi county. The detecting lines were disposed by river front, dike back and dike axes. The three instruments were tested sequentially. The testing result was put forward to program group in order to compare the detecting level of three instruments. From 1996 to 1997, the program group arranged pressing grout for testing dike section. In March 1997, we dug out the grouting section and testified the detection result.

At same time, in December 1996, we dug out and testified the result in Dongpinghu lake dike. The digging result indicated that the location, trait, trends, developing status and hidden depth fit with the results of Shandong bureau and Yellow River design Co.

### **3 Analysis and estimation of efficiency**

In order to master the quality status of Yellow River dike it can be found much hidden dangers in time by detection. In light of dike earth status and distribution of hidden dangers, we duly laid out the scheme of flood control and purposefully prepare flood control materials for various danger situation, and judge and rush to deal with all emergencies and set up files of dike hidden dangers in time. Through reinforce all kinds of dike, we ensure the safety of all flood control projects meaningfully and obtained great social profits. The main bases we dealt with dike before principally depended on historical breaches, penetration section, slide slope and fissures etc, and this lacks of scientific foundation. Since 1996, the detection work has been carried out on large scale, so far, the total detected dike sections obtained to 95 and the detected length is 748.57 km, the hidden dangers sites being discovered are 783, the grey – staged charts being pictured or color – graded ones are 932. The application and popularization of detection technology provided scientific dependence for dike reinforcement. It has much pertinence and avoids extravagant human and property. Thus capital can be used in weakest site and accomplished double effect and created utmost economic profit.

At present, the popularized instruments made by Yellow River design Co. and Shandong Yellow River bureau possesses much priority in detection rate and effect than traditional methods and this can not be done by other instruments. Detection with this instrument possesses advantage of saving time and reliable outcome. Compared with traditional methods, such as pole probing and bar probing and dike soaking etc.

### **4 Perspective of application and popularization**

According to the rules of maintenance regulations of dike engineering, the department of dike management has reliability to detect the important dike base and dike slope that probably exists hidden dangers. In terms of gist of water projects maintenance quotient issued by water resources ministry and finance ministry, the dike hidden dangers detection should be carried out on schedule. As for the first grade dike of our country, the dike should be detected once ten years. After the mechanism reformation of water management, it provides policy facilities for dike hidden dangers detection, and detection fares was guaranteed, thus the detection work possesses widely perspective. Because of high – technical work and difficult estimation in detection of hidden dangers in Yellow River dike, it should not to adopt management mode of planning times any more. As to detection mode completed by water management bureau itself, it should be according to needs of market of water project maintenance to select qualified research unit in finishing detection task in order to ensure the veracity of detection and offer dependence for Yellow River dike management.

### **5 Conclusions**

From the digged results and application of ten years there exists much priorities in use of electricity detection methods, such as advantageous technology, convenient operation, practicality and high detection veracity. Electricity detection methods can be used to find out the hidden dangers location, characteristics, evolutionary situations and hidden depth of fissures, caves and soft earth layers. Concurrently it obtained favorable effect in analysis of general quality of dike and water penetration aspect.

## Urgency and Countermeasures for Governing Sand Mining in the Qin River Channel

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**Abstract:** Due to lacking of systematical sand mining programming, the sand mining in river channel in the Lower Yellow River and Qin River affects flood control, river training and water administration. While the urgency of sand mining programming in the lower Yellow River and Qin River is demonstrated, the countermeasures of sand mining management are proposed: ① publication should be done to ensure the safety of flood control; ② the programming of sand mining should be made as soon as possible; ③ the law should be executed, etc.

**Key words:** sand mining, flood control, programming, urgency, countermeasures

The Yellow River is well – known for its less water and more sand and the secondary suspended river. Sand makes the Yellow River apt to change and breach and brings disasters to the people on both banks. But water and sand resources are convenient for diverting and make great contribution to the development of industry and agriculture on both banks, such as pumping sand to strengthen embankments and decrease sediment deposition so as to ensure the safety of the embankment, and coarse sand used for construction materials to promote the development of local economy. However, the phenomenon of mining in disorder and excessive digging becomes severe at present in the lower reaches of the Yellow River and the Qin river. Here sand mining refers to sand mining, stone mining, soil taking and panning in the scope of river management. Additionally, there is no systematical programming of sand mining in river channel, which greatly affects the safety of flood control of the Yellow River and the Qin River, destroys the effective management of the river training and fetters the behavior of execute the law of water. Therefore, effective countermeasures should be made to improve the sand mining status quo in the lower reaches of the Yellow River and the Qin River.

### 1 Sand mining status quo in the lower reaches of the Yellow River and the Qin River

The river channel of the lower reaches of the Yellow River is 786 km. The area of the floodplain is approximately 4,000 km<sup>2</sup>. There are 1,810 thousand people living in the flood plain. To strengthen the embankments by using sand in floodplain and the main channel is an important measure to ensure the safety of the embankments in recent decades of years. Yellow River is wide between both banks in Henan reaches. Large – area of floodplain supplies sufficient earth resources for strengthening the embankment while it meets the needs of production and living of the people. The engineering of warping to strengthen the embankment brought great social benefit. However, for many years earth has been taken from nearby in order to shorten the transporting distance and save money. At present, pits and ponds caused by strengthening the embankment near the embankment scattered all over like stars. If large flood occurs, rolling river is very easy to form, which will cause flood flowing along the embankment and threaten the safety of the embankment.

River course on the transition reach from valley to plain is an ideal sandstone resource for construction. Sandstone piles here due to steep slope and torrential current. It is rich in sandstone in the reaches of Mengjin and Mengzhou below Xiaolangdi Reservoir on the Yellow River and the reaches of Jiyuan and Qinyang below Wulongkou on the Qin River. It has been mined frequently since 1970s. With the rapid development of the economy, sandstone mining scale in these reaches has become larger since 1990s. They mainly are: digging up and crushing pebble from the river

course, coarse sand and bed material taken for construction. Preferable economic benefit has been achieved, which makes a certain contribution to local economic development. Excessive digging in disorder in main channel or the scope of river course management and protection has been caused river regime changing of part reach and occurring of dangers, which affects severely flood control, river training and environment, etc. of the Yellow River and the Qin River.

## **2 Urgency for sand digging management**

### **2.1 To threaten the safety of flood control**

The safety of the Yellow River is crucial to overall situation. Flood control is the first task of river administration agency. It is the responsibility of the workers on the Yellow River and the Qin River to protect the safety of the Yellow River and the Qin River. Sand digging in river course is not only related to the safety of river course and flood control engineering but also sand diggers. It has been prescribed definitely in “Water Law”, “Flood Control Law”, “River Course Management Regulation in Henan Province”; sand digging in river course cannot affect flood progressing and approved by the river administration bureau. Sand digging in river course is usually at the place near the engineering works, such as between dykes, abutment head, etc., where it is rich in sand. But digging here is very easy to lead the current rushing dyke, cause danger of the dyke and threaten the safety of the dyke.

Sand and stone taking in riverbed makes riverbed lowered; ponds and pits formed after sand taking, which detains water current. The time of flood evolution changes when middle – size and small – size flood occurs, which increases the uncertainty of flood forecast. Besides, sand piles usually are in the shallow place of the main channel. It is very easy to block river course and change river regime and cause large danger if they are not cleaned in time.

In former warping to strengthen embankment, programming of material yard usually takes consideration of the reach that is warping to strengthen in order to meet the need of its technical criteria without considering the whole embankment. It is easy to lead ponds and pits of material yard of different time and different reaches linking up. Rolling river, flood flowing along embankment are prone to form and threaten the safety of embankment if large flood occurs.

### **2.2 To destroy the effective training of river course**

River course training is an effective flood control measure to keep river course stable and ensure the safety of the embankment. Sand digging in disorder in river course changes the boundary condition of riverbed, which causes configuration change of riverbed. Sand digging in main channel would affect the current direction. River regime change would make danger occurring in river training works or cause large area of floodplain collapsing and main stream not flowing along the works. For example, sand and stone taking near Number 5 groyne of Tiexie vulnerable spot in 1997 ~ 1998 in the reaches of Mengjin on the Yellow River caused the current making curve below the Number 5 groyne and large area of the floodplain on the right bank collapsing, which led the Lucun works far away from the mainstream in 1999. Sand digging in the upper part of Kongcun vulnerable spot on the Qin River made inclining river worsened and to some degree led large danger occurring in Kuncun vulnerable spot in August, 2003. The upper part of the lower reaches of the Qin River is usually taking place sand digging due to the small current. But once large flood occurs, river regime is easy to change and threaten the safety of the embankment.

With the carrying out of warping to strengthen the embankment in recent many years, ponds and pits of sand and stone taking are great deal and spreading out. Once large flood occurs, they are linking to form bunching river and new river and easy to lead danger occurring in the embankment without training works.

### **2.3 To restrict the behavior of river administration**

Yellow River Henan Bureau and its affiliated bureaus are the departments in charge of the river

administration of the Yellow River and the Qin River. River administration is the main function. Sand digging in disorder in the river course of the Yellow River and the Qin River offends "Water Law", "Flood Control Law". At present, only "Sand and Stone Taking Administration Measures in River Course on the Yellow River and the Qin River of Jiaozuo City" was made. It requires; river administration agency of county level makes river course programming by the overall programming of flood control, river training programming and status quo of the river and approved by river administration agency of city level and implements it strictly.

The upper part, lower part of the lower reaches, right bank and left bank of the Yellow River and the Qin River are governed by different units. Sand and stone taking boats from different units strive for sand sources, which causes conflict. It made society unstable and affects the development of local economy.

Ponds and pits are uncovered in dry season. Villagers and children usually swim or play in them. Drowning occurring now and then causes conflict and affects the work of river administration bureaus.

Ponds and pits in high floodplain were planned to be filled by silting again. Due to no large flood to the lower reaches of the Yellow River in recent years, the ponds and pits fill with water the whole year, which affected the agricultural production of the local people. This leaving - behind problem has been a factor causing society unstable of individual region.

#### **2.4 To restrict the development of local economy**

The transition reach from mountain to plain or the upper part of the lower reaches of the Yellow River and the Qin River is rich of sand and stone, which has been the origin of becoming rich of local people. Sand and stone taking in order is needed. Over 400 thousand  $m^3$  of sand and stone is taken every year in Qinyang section of the lower reaches on the Qin River. More than million  $m^3$  sand was taken in Mengzhou section on the Yellow River. Sand and stone taking in order under the rational programming would promote the development of local economy.

#### **2.5 To affect the ecology of riverbed**

To protect the ecology of riverbed is the key measure to prevent sand blown by wind in river course and also one of the means to realize the safety of flood control. Sand and stone taking in disorder in riverbed makes the natural river course with branches becoming single river course. River island and natural wetland will disappear; sand and stone digging in new floodplain destroys the natural plant; sand digging deep in riverbed causes the unstable of the slope and the losing of the earth, etc. The ecology of riverbed is destroyed.

### **3 Countermeasures of sand and stone taking management**

Sand and stone taking management in the river channel or in the scope of river course management and protection in the lower reaches of the Yellow River and the Qin River should strengthen publicizing of related law and regulation to ensure the safety of flood control. Sand and stone taking programming in river course should be made as soon as possible. The law of water administration should be executed. The needs of flood control, river training, water administration and the development of local economy should be planned as a whole. The upper part and lower part, right and left banks of the lower reaches should be given attention to. The inflow of water and sand of recent years should be analyzed to program rationally and mine effectively.

#### **3.1 Propagandize should be strengthened to ensure the safety of flood control**

In "Water Law", "Flood Control Law" and "River Course Administration Regulation of the Yellow River and the Qin River in Henan Province", it is required; sand and stone can be taken in

the scope of permitted river course; it is not allowed to take sand and stone in the scope of engineering protective zone to destroy the stability of the engineering; it is not allowed to take sand and stone in main channel to affect river regime; sand and stone are not allowed to pile in new floodplain to affect the progressing of flood, etc. This content should be propagandized through media such as broadcasting, television, etc. and slogan, printing plate, etc. to make people known on both banks. The activities during the period of "Water Law Propagandizing Week", "World Water Day" were organized very well; training class of law publicizing should be organized to train the representatives of the villagers; encouragement fund should be established to put a premium on the personnel of reporting those lawbreakers. It can increase the law conscience of the people through these means to reach the aim of keeping the peace and obeying law.

### **3.2 To work out the sand and stone taking programming in river course**

Sand and stone taking programming in river course is the basis of sand taking. The main reason of excessive sand and stone taking in disorder in river course is lack of a rational and effective sand and stone taking programming, which needs to be worked out and issued for enforcement as soon as possible. Sand and stone taking programming should be worked out by water administration unit higher than county level according to rational programming and making overall plans and taking all factors into consideration. The inflow of water and sand and necessary size analysis of riverbed sand should be carried out. The change of the river regime and the evolution trend of floodplain and shore should be studied. The upper and lower parts, right and left banks should be given more attention to.

Perfect and systemic programming of material yard for warping to strengthen embankment of the lower reaches on the Yellow River and the Qin River should be made. Earth is taken to protect plantation and the safety of the life and property of the people in floodplain. Sand and stone taking place should be far away from the embankment and village. If possible, flood diversion should be done to silt the ponds and pits.

#### **3.2.1 Content of sand and stone taking programming**

The contents of sand and stone taking programming are as follows:

- (1) Prohibited zone for sand and stone taking and approved zone for sand and stone taking should be divided.
- (2) Prohibited period for sand and stone taking and approved period for sand and stone taking should be defined.
- (3) Scale of sand and stone resources that can be taken should be regulated, including depth, scope, quantity, etc.
- (4) Supply of sand and stone resources and the overall control of yearly sand and stone taking should be narrated.
- (5) Selection of equipment and work methods should be narrated too.
- (6) Plane graph of sand and stone programming should be shown.

#### **3.2.2 Sand and stone taking programming should follow river training programming strictly**

River training works is the key measures to make river regime flow along the river course smoothly, prevent the floodplain from collapsing and ensure the safety of the people in the floodplain and the embankment. With operation of the reservoirs such as Xiaolangdi Reservoir, the possibility of flooding the floodplain in the lower reaches of the Yellow River becomes less. River training works plays a more important role. The form of high floodplain and deep channel of the main course is river training to meet the need of flood progressing of medium and small flood. Sand and stone programming of the Yellow River and the Qin River should be made by recently approved river training programming.



### 3.2.3 Sand and stone taking by stages and zones

Sand and stone taking in the sand and stone taking programming of the Yellow River and the Qin River should be done by stages and zones. The supply of sand and stone is an important aspect of the programming by zones. Taking by stages should take full consideration of the inflow of water and sand in different period. When sand and stone can not be supplied in time, excessive taking should be prohibited. Sand and stone taking programming should be changed with the change of river regime and the inflow of sand and stone. Sand and stone taking should follow the latest approval programming.

### 3.3 Administration of law in water should be forced

The key is to execute the law no matter about law strengthening, propagandize, regulation, programming established. If law can not be implemented, the situation of disorder sand mining and digging can not be changed ultimately. So we should strengthen the power of law implementation. It is one of the main function of the departments of river training management; water administration bureaus should depend on the local government and judicatory and execute the law strictly, take the fee for sand mining management and deposit for sand mining. Obstacle in the deserted sand mining place should be cleared, such as wood stake, weaving bag, etc.

## 4 Conclusions

Propagandizing should be done. The law should be executed strictly. Sand and stone taking programming should be made and issued under the precondition of meeting the need of flood control and river training of the lower reaches of the Yellow River and the Qin River. It is urgent and necessary to ensure the safety of flood control, river training works, the life and property of the people in the floodplain; solve the conflict of sand and stone takers and administration department of law in water; promote the development of local economy. Water administration department should exert its water administration function, make the integral programming of sand and stone taking from the upper to lower of the lower reaches to standardize sand and stone taking behavior according to the demand of "To Strengthen Sand and Stone Taking Management of River Course all over the Country". Task should be defined, responsibility should be fulfilled, and ensure the Yellow River and Qin River safety forever.

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# Comprehensive Effect Analysis of River Regulation Programs and Measures in Different Rivers

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**Abstract:** Owing to the different geographic locations and the different conditions which are underlying surface of river erosion, its water – sediment characteristics and riverbed conditions are obvious different. Countries in the world launch different regulations and exploitations in view of the own characteristics of rivers and the mission of rivers that have taken the necessary regulating program for the certain purpose, adopt various regulating measures and programs. The regulating programs and measures and dam forms adapt greatly the basic characteristics of river or not, which is a matter of concern. Therefore, this paper, on the basis of overall analyzing the regulating programs and measures of some typical river at home and abroad, broadly summed up 6 typical regulating programs, gave a brief presentation of the river training situation, then put forward the correlations between the aim of regulation and training programs, measures.

**Key words:** the aim of regulation, training programs, engineering measures

As is well known, owing to result of interaction between flow and riverbed, most of natural channel morphologies are bend and one after another reverse curve bend. River regulation often conforms to the development of river regime, follow the basic law of fluvial process and adopt homologous regulating measures and the disposal pattern.

Because their regulation purposes are different, the river regulation programs of the different rivers are more suited to the river's own characteristics. On the basis of the river regulation program, regulating measures and corresponding engineering form are chosen.

According to the analysis of the typical river which is at home and abroad, the different channel regulation purposes of the regulation measures comprehensive analysis as follows:

## 1 Single shore regulating measures of the sandy river with the purpose of controlling engineering to control fluvial process and insuring flood control safety

### 1.1 The purpose and measure of the single shore sandy river regulating measures

The typical river actualizing single shore sandy river regulating measures has the Yellow River and the Liaohe River, water sediment and riverway characteristics of these two rivers have a total of three characteristics: ① floods violently go up and down. ② Sandy (alluvial) river, the river has changed loitering; ③ arduous flood task. So the regulating purpose is basic same, it is to improve the river shape of the cross – sectional and the plane, control mainstream, stable fluvial process, under the premise of ensuring the safety of flood control, in favor of irrigation and production in the flood plain. Training measure with based regulating engineering and the supplement of meander cut – offs and dredging.

The river training project of the Yellow River downstream is slightly curved regulation. We make construction project only in the concave bank. "Making the spur dike to protect the bend, making the bend to leading the main stream" is the river regulation's principle of the Yellow River downstream.

The micro bend river training program is also used in the Liaohe River. For wandering river, we construct the short spur dikes in the concave bank which is danger. At the same time, meander cut – offs which is necessary is carried, which could control and guide the main flow, protect the embankment, stabilize the river regime, so the river could translate to micro bend type. For

wandering river, we generally arrange crony in the concave bank which often occur erosion, which could protect concave bank, greet the mainstream, and maintain the existing river regime.

## **1.2 The situation of single bank training project of the sandy river course**

After three decades of exploration and practice in the Yellow River micro bend – rectification program, we have made the wandering area of wandering river smaller than that of natural conditions. The water flow condition and the cross – sectional shape were improved, and the probability of "cross river, ramp – river" was reduced, then the safety of flood control was enhanced. River regulation projects effectively prevented the collapse of flood plain and improved the conditions of the diversion and water supply reliability of industry and agriculture. But there are also some problems; some sections of adapt poorly to the new conditions of water and sediment, river training works is imperfect, often appear adverse river regime, strength of the already constructed building works is scarcity, stability is poor.

The Liaohe River downstream training projects which have been completed in accordance with planning requirements and have suffered the three floods in 1986, 1989 and 2005, protect the safety of flood control in the riverine areas and make remarkable economic and social benefits. Especially, integrity of short gabion groins which are adopted in the wandering river part of Liuhekou to Hongmiao Bridge is better. It could fight against larger flow and overflow and play a crucial role in stabilizing the river regime. The scope of loitering has been significantly narrowed so as to stabilize the river. There are some problems, for example, that groins suffer serious erode from reverse current among groins and meet with dangerous situation in the flood period. However, in recent years, because in the Liaohe River course the obstruction has been cleaned out, and the flood houses and local people have been moved, the assignment of flood control in the flood plain is obscure. People generally don't rush to deal with an emergency in flood season, then rehabilitating the works after the floods.

## **2 The training projects of more water and less sediment river which for the purpose of protecting bottomland and bank, assuring shipping and ensure safety of flood control**

### **2.1 The purpose and measure of the single – sides of the more – water and less – sediment river**

This typical representative river is the Yangtze River. Its average annual runoff into the sea for years is up to 960 billion  $m^3$ , which accounts for over one – third of the total water amount of China's rivers into the sea, and its turbidity is not big. During the flood period frequently reaches top form beachfront, which causes beach collapsed. Mainstream flows along the larger horizontal direction which leads to the river course to swing largely, even threaten the safety of people's lives. The purposes of the Yangtze River' training are to protect the riverbank and the safety use of flood control projects, to heighten the stem stream discharge capacity, to maintaining the waterway depth, and to ensure the safety of flood control and safety of navigation. In training projects, bank protection works are main measures, meander cut – offs and dredging are assistant measures.

### **2.2 The situation of the single shore regulating measures**

Most of regulating works in the middle and lower reaches of the Yangtze River are large – scale revetment works and meander cut – offs projects. Revetment works mainly include flattened revetments, rock spurs retaining wall and spur dike revetment. For years practice indicated that two revetment structures, riprap and mattress, are successful relatively.

Total length of revetment construction is over 1,100 km in the middle and lower reaches of the Yangtze River. There are two meanders cut – off in the Xiajingjiang, and five braided river plug fork.

With the construction of bank protection works, there are the advantages as follows: decrease of collapse, stability of river regime and protection of embankment. But some problems mainly occurred in two aspects. Firstly, after the spur dike revetment built, flow direction's changes have an negative effect on flow pattern of main channel; Secondly, when meanders cut - off of the Jingjiang alleviate the flood control pressure and get some ship benefits, the evolution of the river bends becomes faster, and the serious collapse also threat agricultural and industrial production.

### **3 Channelized regulating program with the purpose of urban flood control**

#### **3.1 The purpose and measure of city channelized regulations**

Riverway channelized is to reform the natural river into the regulated channel with the parallel shores through some projects. In order to insure the safety of urban flood control, channelized regulations and strengthening the border of river are often used in urban river regulation.

Specific measures of channel regulations are strengthening river bank and narrowing riverway. Riverway channelized costs are high. In Europe, the United States, Japan and some other developed countries, the sections of near towns and even entire sections of many rivers have been channelized; some important cities also have implemented the riverway channelized in China.

#### **3.2 The situation of the rivers channelized**

Rhine River, an international river, is the largest navigation river in Europe which runs through Central Europe, Western Europe. There are many famous cities along Rhine River. So every country takes the measures of strengthening river bank to ensure the safety of urban flood control.

After the renovation of the Rhine River channels the restrictions on the transversal deformation erosion, curbing of the collapse, and stabilized the river regime can greatly reduce chances of the dangerous conditions occurring and the losses of the large amount of land which caused by collapse, and raise the standards of flood - control. However, it also leads to the serious river bed erosion. In order to solve the serious river bed erosion problem, France and Germany ever had an agreement to build Neuburg Weir; however, this weir wasn't built because of some reasons. To stabilize the river bed, governments were obliged to dump bed loads into river bed. For example, in 1978 to 1985 the annual average amount dumped is 167,000 km<sup>3</sup>.

The shipping conditions have greatly been improved by excavation of a large number of artificial canals and channelization, which promote the development of the shipping industry in the Rhine River.

### **4 The renovation measures of navigation channel of inland rivers**

#### **4.1 The purpose and methods of the renovation measure**

Generally speaking, this kind of renovation often uses engineering measures to limit the channel in a certain range in order to make sure the water depth, width and mild turning of the river in safe navigation level.

There are many engineering measures of navigation channel renovation, for example using closure dams to clog branches of river and using the groin of guiding flow to assure the width and depth of navigation channel. Besides the measures above, dredging up and cut - off are the two common assistant measures.

Recently, the inland river renovation about navigation always adopts dams to cut off the bends, at the same time, dredging up, as assistant measure, is used in restricting river and assuring depth water of navigation channel.

## 4.2 The examples of implementing the renovation

This kind of renovation plan—use dams to cut off the bends with dredging up to firm the river—are wildly used on many rivers, there are some examples of this renovation.

### 4.2.1 Missouri River

The Missouri River has plenty of water and much sediment in United States. In its middle and down stream channel the renovation is mainly used to make navigation channel steady, and cut – off and dredging up are also adopted in this channel to make it without clogging. Besides, different kinds of dams are built to limit river and firm navigation channel. The light permeable structures are often adopted in dams, like permeable timber pile, abandoned and shabby cars. Rockfill or concrete is the main materials in bank protection. With the renovation, the Missouri River now becomes bend river, and the navigation condition is improved, the depth of navigation water is deep from 1.96 to 2.1 m.

### 4.2.2 The Rhine River in Holland

Holland is the last country the Rhine River flows across, and North Sea is its destination. In Holland the Rhine River is 170 km long, and is the biggest river in Holland. Holland not only uses embankments and controlling and conducting projects, but also uses digging channel, cut – off, making river as ditch, clean the clogging.

By the end of 1850s, a huge controlling and conducting projects composed of more than 1,600 dams have been finished in the Rhine River according to three aims: firstly, avoid bottomland in the bank of bend outside to be eroded further more; secondly, rise water level especially in low water season navigation; thirdly, decrease the effects of waves eroding banks when navigating. According to the safe navigation requirements, there are dams which are always long (some of them are even as 1/3 of river width) lies in both sides of most parts of the river no matter whether the part of river is bend or straight.

These engineering measures improve navigation condition of the Rhine River largely, and promote the development of its shipping industry. So far, the 7,000 t ship could pass through the river to Köln harbor, Germany.

### 4.2.3 The Elbe River

The Elbe River slanting crosses depressions of plain in the north of Germany. It flows slowly, and the drop is low. After it passes Hamburg, it goes to the place which is 10 km to the west of Brunsbuttelkoog to pours into North Sea. The aim of renovation in this river is to limit the channel and firm the beach of banks so that the depth and steady of the river are good for navigation. In this renovation, it adopts dams to achieve its goal, and changes its navigation condition positively.

### 4.2.4 The Hanjiang River

The part of the river which is between Xiangfan, Hanjiang and Hankou adopts the renovation, using different kinds of dams to firm the channel, cut – off and dredge up to make it unobstructed. When the renovation is completed, safe navigation under mild low water situation is satisfied, the channel is stable, and the condition of the channel and harbor is improved. After the renovation, the minimum depth is above 1.6 m, the width of the channel is increased to 80 m, and the minimum bending radius is also increased, which is from 250 m to 340 m. All of these mean that the 500 t ship and 2,000 t shipping groups could pass the river, navigation guaranteed rate is up to 97%, reached a milestone in the mainstream navigation 1,313 km, and the part of the channel which is below Danjiangkou reaches the 4th level.

According to the analysis on the examples above, the channel of inland river adopts the renovation could limit the river, avoid channel swinging largely, assure the depth and width of the

river and firm the channel. Though using dams, cut – off and dredging up to renovate the channel is an effective engineering measure, problems still exist. Firstly, the renovation on two banks ought to work at the same time; it means a large amount of one – time investment and a long time limit for the project exist. Besides, it's hard to deal with the river whose flow changes largely. Secondly, the investment and complexity of the project will be increased because of higher requirement of the material of the dam based on the erosion of the head of the dam. Thirdly, the cut – off of the renovation has greatly effect on a part of river. The dam foundation and bank protection will be eroded intensely as the result of the capability of carrying sand in water is intensified after cut – off project shortens the channel. Further more, the deposition problem in downstream is distinct after cut – off. Therefore, cut – off project must under well control, otherwise, all these efforts wasted.

## **5 The banks of estuarine navigation channel renovation measures**

### **5.1 The purpose and methods of the renovation measures**

Estuary is not only the place which is used to contain excessive water of the river, but also the junction of the river and the sea, the gateway to the land and the sea links, and even the important military bases. Sediment in estuarine coast is viscous, and small in particle – size, so it's very easy to become flocculated structure. Most of estuaries are changed to sedimentation sand bar or shoal, also become the main obstacle to navigation and drainage because of deposition problems.

The estuarine navigation channel renovation is dependent on renovation engineering to renovate banks, adjust flow and navigation depth. It often uses the plan on banks with dredging up measure. That's to say, adopt different kinds of dams to limit the channel as well as renovate banks. By these efforts, the channel is confined in the range of design parameters, and its steady is assured.

### **5.2 Implementation of the river estuary channel renovation on both sides of the river situation**

According to the information we collected, clearing the important estuary of the countries in the world, has got the desired results.

#### **5.2.1 Regulating estuary of special river at abroad**

Most of foreign renovations start from renovating sedimentation sand bars. With the rapid development of international shipping industry in 1850s, the tonnage and drafts increase rapidly, and low depth in sedimentation sand bars becomes the biggest obstacle in estuarine construction. Some developed countries begin renovations such as France, United States, and Holland etc.

Summarize experiences from foreign renovations, the main are:

- (1) different renovation plans with different hydrological sedimentary characteristics;
- (2) it's difficult to renovate estuarine navigation;
- (3) renovation with dredging up measures;
- (4) estuary which is easy to have deposition has obvious seasonal varieties in carrying sand in water, therefore, it needs dredging to maintain the navigation depth after renovation.

#### **5.2.2 Typical regulating estuary of the rivers in china**

##### **(1) Yangtze River estuary**

There is a large amount of water resource in the Yangtze River estuary, which is braided and sandy. From Xuliujing down forwards, the surface was flared. The average annual runoff is 924 billion  $m^3$ , the average flux is 29,300  $m^3/s$ , the average sand quantity into – sea is 486 million t, and the average annual sandiness amount is 0.547  $kg/m^3$ . Over the years, the sea – route of the Yangtze River estuary is wondrously unstable, for that the door – bar sand exist, the natural water depth is less than 6.0 m, the savage water depth is shallower than the door – bar sand in the upper and lower reaches, where the natural water depth on the top of beach is 5.5 ~ 6.0 m. Therefore,

since January 1998, when the first – phase project of the Yangtze River estuary was started, the systemic regulating works has been carried out.

The first regulating problem is navigation , adapt the combination of regulating and dredging measures in order to ensure sea – route expedite , particularly in the regulating of deep sea – route, the general design is the dredge up combined by the north and south wide Waterway and long – crested weir. After the navigation of 8.5 m and 10 m deep sea – route in the Yangtze River estuary, the guarantee rate has reached to 100% , so the navigation conditions of North sea – route has been greatly improved.

## (2) The Qiantang River

From Hangzhou below, the river is suddenly wider, the river flow is smaller without aphytal and the strong wash caused the move of quicksand, which contributed that the rise and sink crossed through the beach and the location of trough changed. So the main purpose of regulating the Qiantang River is to protect the beach and bank, stable and shrink the channel and occupy inning.

The distributions of channel regulating in the Qiantang River varies in different times and were constantly revised and improved while the southern and northern shores of rectification are used in common. The narrow river channel program has been used recently. The regulating project follows the principle of in group, the adjustment in time, and the combination of longitudinal dam and bank. The regulating project in the Qiantang River mainly includes the beach and bank protection, the channel shrinking. The measures are combination of long, short groyn and longitudinal dam, the cofferdam instead of dam.

On both banks of estuary, there are about 545 long or short groyns, which shrink the 64 km – reach between Zhakou, Hangzhou and Shibao, Haining to planning requirements, stabilizing the navigation. The measures above not only stabilized channel but also saved a lot of money.

According to the experiences of regulating channels domestic and foreign in years, the combination of regulating and dredge is an effective way. The programming line should be straight with little curve, the ebb – tide main trough is chosen as navigation trough, make the flood trough the same with the ebb – tide main trough in order to maintain the water depth in channel.

## **6 Opposite groyn regulating measures which are for the purpose of stabilizing the flow path, beach nourishment and brushing river channel**

After sediment – laden river flows into the alluvial plain, it always enters into wandering channel (such as the Yellow River, the Amu Darya River, the Weihe River, etc. ). For those channel of high mobility which is mainly composed of sand soil, sand and clay, the channel is wandering under the impact of water flow, and it leads to strong collapse of riverbed in bottomland. With this end in view, opposite groyn regulating program appears. This section focuses on opposite groyn regulating program.

### **6.1 Regulating purpose and measure of the opposite groyn**

The purpose of regulating opposite groyn is to prevent bank and bottomland from flush and collapse, collect silt soil, deepen main course, and reduce the swing range of riverway, stabilize flow path, etc.

The common measures are acute or right angle opposite groyn.

### **6.2 The implementation status of the river which was regulated by opposite groyn**

The program 's most typical representative is the Amu Darya River in Uzbekistan. James soil Amu Darya River hydropower project downstream to 250 km braided was extremely unstable, river – bed was extremely unstable, it usually form cross river in the flood period and causing flood to destroy the flood plain and bank, to cause collapse of the bottomland, the mainstream flow along the direction of cross slope which is bigger, it causes that riverway is swinging greatly, leads to great

difficulties to irrigate, use land, and threat settlements at the same time.

In the early 1980s, Irrigation Central Asia Institute put up a set of methods which were used on both sides of the river regulating programs, obey river situation, steady flow road, regulating project adopt the acute angle opposite groyne. After the acute angle opposite groyne, the river has been narrowed the scope of wand. The construction of regulating project limit the water width in the flood period, form larger flood plain back whirlpool on the dam crotch, thus contributing to the siltation, sediment deposition exist among a large number of beach, with the water surface elevation. Bottomland silt, the main channel is deeper, so height difference increased, a high – water pool is formed, making swath no chutes; it helps control and direct the main flow, drainage sediment. Make mainstream away from the bank to prevent the bank's collapse, but current is concentrated on the jetty head of acute groyne. The groyne suffers from the strong scouring, the erosion depth is more than 20 m during the larger flood period.

## 7 Conclusions

Based on the analysis of typical rivers at home and abroad, comprehensive effectiveness analysis of the programs and measures of river channel regulating for different rivers as follows:

(1) The single shore regulating measures of the sediment – laden river which are for the purpose of stabilizing the river regime and controlling the mainstream and ensuring the safety of flood control, the Yellow River and the Liaohe River are the typical examples, it is only in the concave bank construct projects.

(2) The single shore regulating measures of more water and less sediment river which for the purpose of protecting bottomland and bank, assuring shipping to ensure safety of flood water, the typical river is the Yangtze River, with two types of bend and bifurcation. The bend river is strengthened on the concave bank and freakish river is cut to line. The bifurcate rectification is due to specific situation, such as revetment, cutting to line, dredge up and branch block.

(3) Channelized regulating program with the purpose of urban flood control is carried out through solidifying bank and narrowing riverway to restrict the channel's cross direction erosion and improve the standard of urban flood control. The typical river is the Rhine River.

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## Impact of Channel Shrinkage on Flood Routing along the Lower Yellow River

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**Abstract:** According to the principles of hydrology and riverbed evolution, the rule of flood routing in the channel shrinkage process was analyzed based on field data and movable – bed model test. The result shows that, no matter how the sediment concentration is, the flood peak reduction ratio will increase and the flattening – out of flood wave will occur in the channel shrinkage process. However, when the flood peak discharge is close to the bank – full discharge, the flood wave transformation is small and so is the flood peak reduction. The advance speed of freshet slowed down and the advance duration prolonged. When the flood peak discharge is about double of the bank – full discharge, the advance speed of the flood reaches its minimum. Even so, the synchronization adjustment relationship still exists between the average velocity and flux of the channel section. The channel shrinkage reduced the wetted cross – sectional area, increased the rising speed rate of the average riverbed elevation, and so increased the rising amplitude of flood stage. After channel shrinkage, the sediment transport by flood still features of “more coming, more silting and more scouring”, and the relationship between sediment carrying capacity and main river channel’s morphology is still in accordance with the general riverbed evolution rules, and has nothing to do with the channel shrinkage mode.

**Key words:** advance of freshet, sediment carrying capacity, channel shrinkage, channel in the Lower Yellow River

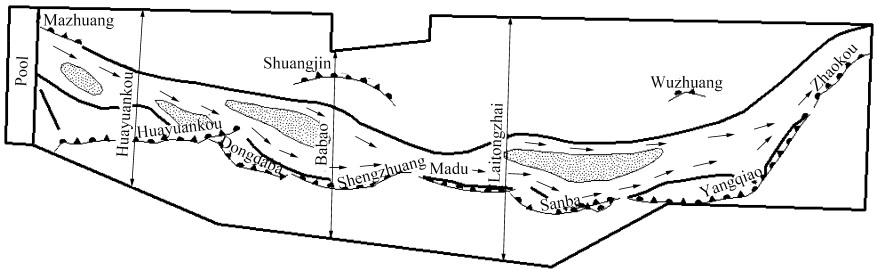
According to the principles of hydrology and riverbed evolution, some high – order response relationship exists between the characteristics of freshet advent and the river’s boundary conditions. Since the middle 1980’s, serious silting and shrinkage of the main riverbed occurred in the Lower Yellow River, which increased the rising speed rate of the average riverbed elevation, reduced the wetted cross – sectional area sharply and so influenced the advance of freshet in the river channel to a great extent. Some researches and discussions have been implemented about the influences of the channel shrinkage in the Lower Yellow River to the advance characteristics of freshet, but generally speaking, most of them are limited to some flood’s advance characteristics or the flood carrying capacity of a river and the water and sediment features of the flood that caused the channel shrinkage, instead of about the variation rule of the characteristic parameters in the advance of freshet under the condition of channel shrinkage, such as the peak flood discharge, flood propagation time and the relationship between water level and flux. What is more, the response relationship between the adjustment of the sediment carrying capacity of floods and the channel shrinkage remains to be studied further. Analyzing the responsive relationship between the advance of freshet and channel shrinkage is a must for us to understand the disaster – causing mechanism of channel shrinkage and to establish the corresponding countermeasures. Based on field data and movable – bed model test, the response relationship of flood routing in the channel shrinkage process was analyzed in this paper.

### 1 Design of physical model experiment

#### 1.1 Choice of river reaches and design of experimental scale

The channel shrinkage in the Lower Yellow River is the most serious river reach and its

evolution process is also very complicated, so we chose it for our experiment. According to the test field and the controlling requirements of water and sediment condition at the inlet and outlet of the model, the simulation reach chosen is the Huayuankou reach, with its inlet located at Beiguotou, and the outlet located downstream of Zhaokou Vulnerable Spot, being 38.45 km long ( see Fig. 1 ).



**Fig. 1 Sketch of the simulation river reaches**

The model is designed according to the similarity law of movable - bed model, and the similarity conditions include flow gravity similarity, flow resistance similarity, flow movement similarity, sediment startup similarity, sediment silt similarity, sediment carrying capacity similarity and riverbed scour - and - siltation similarity. The main scales selected are in Table 1.

**Table 1 The main scales selected**

Different types	Level scale $\lambda_L$	Vertical scale $\lambda_H$	Velocity scale $\lambda_V$	Movement time scale $\lambda_{t1}$	River - bed deformation time scale $\lambda_{t2}$	Settling velocity scale $\lambda_w$	Sediment concentration scale $\lambda_S$	Roughness scale $\lambda_n$
Value	800	70	8.37	95.58	95.58	1.35	2.00	0.60

According to the experimental objective, the water and sediment process of 1987 was selected as the proof test's condition, and the initial terrain was made in accordance with the measured cross - section before the flood season in 1987 when the channel began shrinkage. The outlet water level was controlled by the statistic relationship between the Huayuankou flow discharge and the water level before Zhaokou Gate. The proof test shows that, the model is basically similar to the prototype of river reaches in terms of river pattern, river morphology, water level along the river, riverbed shape and scour - and - siltation, all of which can satisfy the precision requirement.

## 1.2 Experiment scheme

Three typical water and sediment processes were chosen for the experiment, they are 1988 (classified as middle water and plenty of sediment), 1994 (small water and middle sediment) and 1991 (low water and little sediment) respectively. According to the analysis on the measured data, channel shrinkage mainly occurred in a flood season, so only water and sediment conditions at that period were implemented in the experiment. Besides, the silting in 1998 was about 1.8 times of the average for the time series from 1985 to 1996, and the silting on the floodplain was found very obviously, with about 2 m raising up of the main channel elevation. The silting in 1991 was small, accounting for 33 percent of the flood season in 1988, but all the sediment deposited on the main river channel. In order to exhibit the effect of "big disaster caused by small water", we combined the processes of 1988 and 1991 to be one test group according to the variation characteristic of scour - and - siltation in the main river channel. Thus, we considered two types of water and sediment processes in the design of the test group, i. e. the combined type of 1988 and 1991, and "1994 type" (hereinafter called "88 + 91 type" and "94 type"). The initial terrains of the two

types were both made in accordance with the measured cross – section before the flood season in 1987. The experiment period was controlled by the relatively stable state of fluvial process under each test condition.

## 2 Characteristic and mode of channel shrinkage

Through the analysis of field data and test research<sup>[9, 10]</sup>, the channel shrinkage in the Lower Yellow River was mainly expressed by the serious sedimentation in the main river channel, the obvious rise of water level under the same flux and the great decrease of bank – full discharge. So the so – called channel shrinkage in the Lower Yellow River generally referred to the shrinkage of main river channel actually. The major characters of the channel shrinkage are the apparent narrowing of the main river channel, the sharp decrease of wetted area, the visible increment of rising speed rate of riverbed and mutable adjustment of the cross – section shape. It’s also indicated that, the adjustment trend of the cross – section shape during channel shrinkage was not only unidirectional, but varied in line with the water and sediment conditions. Under the condition of “88 + 91 type”, the breadth depth ratio reduced step by step, i. e. the main river channel varied towards narrow and deep. It’s different for the “94 type”; the breadth depth ratio was enlarged step by step, i. e. the main river channel varied towards wide and shallow. So we can call the channel shrinkage mode caused by “88 + 91 type” “concentrated deposition in main channel”, and call the channel shrinkage mode caused by “94 type” “deposition in both floodplain and main channel”. Apparently, the main river channel varies towards narrow and deep for “88 + 91 type”, while towards wide and shallow for “94 type”. In addition, there was still another mode called “silting without channel shrinkage”, i. e. even subject to silting, the major characters of the channel shrinkage such as the narrowing of the main river channel and the sharp decrease of wetted area did not emerge.

## 3 The response relationship between flood advent and channel shrinkage

### 3.1 Effects of channel shrinkage on the flood peak pattern

Influenced by the river’s boundary conditions, the flood peak pattern will change during the propagation towards downstream. The peak pattern can be simply signified by flood peak discharge. The most direct representation of the change of peak pattern was the increase or decrease of flood peak discharge. The increase or decrease extent of peak discharge can be signified by peak clipping ratio generally, which was defined as the ratio of the difference between the upstream peak discharge and the downstream peak discharge to the upstream peak discharge. According to the variation of the peak clipping ratio from 1950s to 1990s at the river reaches from Huayuankou to Sunkou in the Lower Yellow River, we can see that since 1986 the riverbed silting and channel shrinkage have started, the bank – full discharge have been reduced remarkably, the overflowed floodplain has been found quite serious and the peak clipping ratio been increased year by year. Especially after the flood with high concentration of sediment occurred in 1988, the peak clipping ratio above Gaocun was enlarged continuously, and reached its maximum in 1994 and 1995 since 1954. On the contrary, the peak clipping ratio after Gaocun decreased. The peak discharges at Huayuankou during the floods of 1981, 1985 and 1996 were about 8,000 m<sup>3</sup>/s, but due to the different riverbed boundary conditions, the peak clipping ratios along the river were not the same (see Table 2). Before the flood in Sep. 1985, the bank – full discharge was somehow big enough, so no floodplain overflowing happened during the propagation of flood wave towards downstream, and the peak clipping ratio was not remarkable. The maximum peak discharge at Huayuankou and Sunkou were 8,260 m<sup>3</sup>/s and 7,100 m<sup>3</sup>/s respectively, and the peak clipping ratio was 14 percent. But during the 1996 flood, the bank – full discharge was only 3,000 ~ 4,000 m<sup>3</sup>/s, affected by the continued silting and channel shrinkage from 1986 to 1996. Under the condition that the peak discharge at Huayuankou reaches 7,860 m<sup>3</sup>/s, a large scale overflowing of floodplain happened in the

downstream channel. Meanwhile, because of the bigger rising amplitude in the main river channel than in the beach, the water depth in the beach become deeper and the flood detention effect was strengthened, which lead to a clear flattening – out along the river. For example, the peak discharge at Sunkou was only 5,800 m<sup>3</sup>/s, cut down by 26 percent at Huayuankou. The situation in 1981 was similar to that in 1996, due to the smaller bank – full discharge at the beginning of flood (about 4,500 m<sup>3</sup>/s), the peak clipping was obvious, and e. g., the peak discharge at Huayuankou was 8,060 m<sup>3</sup>/s, cut down by 19 percent when arriving at Sunkou.

**Table 2 Statistics of typical peak clipping**

Stations	Peak discharge (m <sup>3</sup> /s)			Peak clipping ratio (%)		
	1981	1985	1996	1981	1985	1996
Huayuankou	8,060	8,260	7,860	4.1	-0.7	9.0
Jiahetan	7,730	8,320	7,150	4.4	9.8	4.8
Gaocun	7,390	7,500	6,810	12.0	5.3	14.8
Sunkou	6,500	7,100	5,800	19.4	14.0	26.2

Further analysis shows that, if the peak discharge of a flood is smaller than the bank – full discharge, the flood can be restricted in the main channel, and the peak clipping will not be too big even some flattening – out happened. If the peak discharge of a flood approaches the bank – full discharge, the flood deformation is small and the peak clipping is the least. Once the peak discharge exceeds the bank – full discharge and overflowing floodplain happens, the peak clipping ratio will increase as the peak discharge increases. The bank – full discharge at different time varies a lot, especially compared with the time around 1986. Therefore, the peak clipping ratio can be different even the floods of the same discharge happen. River silting will reduce the flood capacity and the bank – full discharge, and under this condition middle and small floods can cause overflowing of floodplain, so the peak clipping ratio would be big. So we can take the correlation of peak discharge  $Q_m$  and bank – full discharge  $Q_v$  as the character index to reflect the clipping effect of the river's boundary conditions to flood peak discharge. Therefore, we analyzed the relationship between peaks clipping ratio at different river reaches and  $Q_m/Q_v$  of the main floods since 1950s and established the following equation:

$$Q_{mu}/Q_{md} = k_1 (Q_m/Q_v) + b_1 \quad (1)$$

where:  $Q_{mu}$  and  $Q_{md}$  are the peak discharge of upstream and downstream sections, respectively;  $k_1$  and  $b_1$  are the slope coefficient and intercept, respectively (see Table 3). Obviously, due to the reduction of  $Q_v$  after channel shrinkage  $Q_m/Q_v$  will become bigger, which cause a more evident peak clipping effect regardless of the concentration of sediment.

**Table 3 The values of  $k_1$  and  $b_1$  in Eq. (1)**

Flood Type	River reaches	$Q_m/Q_v$	
		$k_1$	$b_1$
Low concentration of sediment	Huayuankou—Jiahetan	-0.06	1.062
	Jiahetan—Gaocun	-0.05	1.004
	Gaocun—Sunkou	-0.08	1.022
High concentration of sediment	Huayuankou—Jiahetan	-0.32	1.224
	Jiahetan—Gaocun	-0.50	1.300

### 3.2 The response of flood travel time

Because of the flattening – out of flood due to channel shrinkage, the flood propagation velocity

will be influenced. As for a river with a regular section, the relation of flood peak propagation velocity and the mean velocity in section can be described as:

$$\omega = AV \quad (2)$$

where:  $A$  reflects the effect of river channel configuration on the flood propagation characteristic, calculated as follows:

$$A = \frac{5}{3} - \frac{2}{3} \frac{R}{B} \frac{dB}{dZ} \quad (3)$$

where:  $R$  is the hydraulic radius,  $B$  is the width of the channel,  $Z$  is the water level. The equation above shows that the increase of wetted area will reduce the mean velocity in section sharply if overflowing of floodplain happens, under the condition that the flood peak exceeds the bank - full discharge for a fixed section, thus reduce the flood peak propagation velocity. The bank - full discharge before 1986 was about 5,000 m<sup>3</sup>/s, but reduced to 2,000 ~ 3,000 m<sup>3</sup>/s since then. It can be seen from the analysis of the variation of the mean velocity in section (Table 4) that, the mean velocity is the biggest near bank - full discharge and that of any other rank of discharge is smaller. Moreover, the smaller the bank - full discharge is, the bigger the proportion of flow through beach is, and the smaller the mean velocity will be. At the beginning of "96.8" flood, the mean discharge at Gaocun was 2,800 m<sup>3</sup>/s, about half of that before 1982 and 1958 floods. After the large scale of overflowing of floodplain, the mean velocity was only 0.54 ~ 0.80 m/s, about 1/3 ~ 1/5 of the velocity under the same discharge in other years, and also only 1/2 of the velocity during the floodplain time in 1982 and 1958. Compared with the same level of flood in 1981, the mean velocity of "96.8" flood was only 43% ~ 55% of the former, and the corresponding propagation time was about 1.43 ~ 2.62 times of the former.

**Table 4 Statistics of the mean velocity in section of typical flood at Gaocun hydrological station**

Discharge (m <sup>3</sup> /s)	Mean velocity in section (m/s)				
	1958	1981	1982	1985	1996
2,000	1.69	2.22	1.52	1.81	2.40
3,000	2.08	2.50	1.88	1.97	1.38
5,000	2.55	2.38	2.32	2.09	0.54
7,000	1.20	1.62	2.45	2.56	0.70
10,000	1.03		1.89		

A further analysis shows that, if the peak discharge was double of the bank - full discharge ( $Q_m/Q_v = 2$ ), the flood propagation speed would be the smallest. For example, in 1996 the situation was just like what we talked above, and the propagation velocity was only 1/3 of that near bank - full discharge. If  $Q_m/Q_v$  was bigger than 2, just like 1957 and 1958, the flood flow will fill all the river channel, and the width of the main current will be enlarged, thus the propagation velocity will decrease with the increase of  $Q_m/Q_v$ .

According to the analysis of the model test, even though channel shrinkage can cause the reduction of the propagation velocity and the increase of the propagation time, a good following relationship still exists between the mean velocity and the discharge, i. e. the bigger the discharge is, the bigger the mean velocity will be. Moreover, no matter what shrinkage mode it is, a close proportion relationship exists between discharge and velocity, and under this condition, as long as the discharge increases, we can keep a bigger velocity in the main river channel, and thus improve the shrinkage situation.

### 3.3 The response of flood stage

According to Manning roughness equation, if the discharge of main river channel rises to  $Q_2$

from  $Q_1$ , the increased water level can be calculated as:

$$\Delta H = (Q_2^{0.6} - Q_1^{0.6}) (BJ^{0.5} n^{-1})^{-0.6} \quad (4)$$

We can see from Eq. (4) that a close nonlinear relationship exists between the amplitude of water level and the river width and the roughness of the riverbed. Through further calculation, we know that if we double the roughness or cut the river width by half, the water level will be increased to 1.52 times of before. In the same manner, if we cut the water level gradient by half, the water level will be increased to 1.23 times of before. As described above, the present average width of the two river reaches of Huayuankou—Jiahetan and Jiahetan—Gaoacun was about 60% of that of 1980s, and it can be calculated that water level rising amplitude will be increased by 36% under the same discharge. If the comprehensive Manning roughness coefficient of the beach inside the production dike increased from 0.015 to 0.03 ~ 0.04, the rising amplitude of water level will be increased by 25% to 42% under the same discharge. Assuming that the gradient of water level of the beach equals that of the main river channel, and if the comprehensive Manning roughness coefficient of the beach between the production dike and river dike increases from 0.025 to 0.06, the rising amplitude of water level will be increased by 69% under the same discharge.

According to the statistics of the field data of all the hydrological stations at different river reaches in the Lower Yellow River, there is a relatively close relationship between the rising amplitude of water level under the same discharge and  $BJ^{0.5}$ , the result of regression analysis is as follows:

$$\Delta H = 5.55 (BJ^{0.5})^{-0.65} \quad (5)$$

Statistics of the parameter  $BJ^{0.5}$  of the river reaches after 1985 and 1997s flood seasons in the Lower Yellow River shows that the narrowing of the main river channel sharply affects the rising amplitude of water level (see Table 5).

**Table 5 Influence of the width of main channel on the rising amplitude of water level under different bank – full discharge at different reaches**

River reaches	The width of main channel(m)		The ratio of 1997s and 1985s (%)	The rising amplitude of water level (%)
	1985	1997		
Tiexie—Huayuankou	1,586	921	58	42
Huayuankou—Jiahetan	1,432	923	64	33
Jiahetan—Gaoacun	1,208	727	60	39
Gaoacun—Sunkou	879	695	79	16
Sunkou—Aishan	610	544	89	8
Aishan—Luokou	54\14	507	99	1
Luokou—Lijin	490	431	88	9

It is indicated in Table 5 that, the width of the main river channel of the wandering reaches above Gaoacun in the Lower Yellow River after 1997s flood season was about 60% of that after 1985s, and the rising amplitude of water level under the same discharge was increased by about 40%.

#### 4 The response of sediment carrying capacity to channel shrinkage mode

According to the analysis of the sediment characteristic of different river reaches at different periods, the sediment characteristic in the Lower Yellow River can be described as “less coming, less silting and less scouring”, and calculated as follows:

$$Q_s = KQ^n S_u^b \quad (6)$$

where:  $Q_s$  is the sediment transport rate to represent the capacity of transporting sediment,  $t/s$ ;  $Q$  is the discharge,  $m^3/s$ ;  $S_u$  is the sediment concentration of the coming water from upstream  $kg/m^3$ ;  $K$

is the coefficient, relevant to the preceding scour – and – siltation condition,  $a$  and  $b$  are the exponents, relevant to the boundary conditions and the grading of the coming sediment.

Zhao Ye’ an et al. analyzed the relationship between the sediment transport rate of the whole section in flood season at Huayuankou and the discharge and the sediment concentration of the previous station:

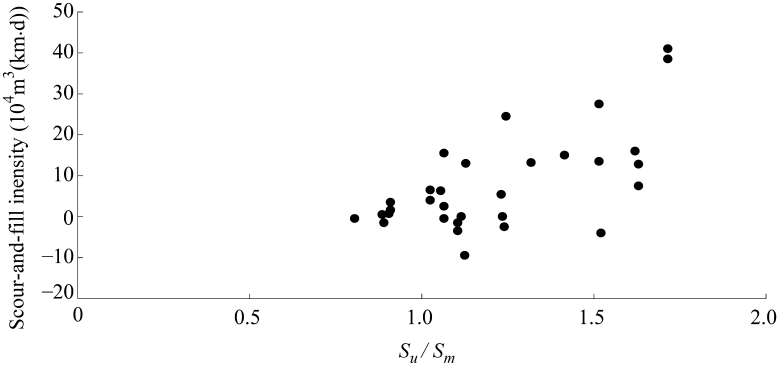
$$Q_s = 1.43Q^{1.16} S_u^{0.6} \tag{7}$$

Based on the equation above, the sediment transport capacity under the condition of “more coming, more scouring” was calculated as follows:

$$S_m = 1.43Q^{1.16} S_u^{0.6} \tag{8}$$

where:  $S_m$  is the corresponding sediment concentration of the sediment transport rate  $Q_s$ ,  $\text{kg}/\text{m}^3$ .

Estimating the variation of scour – and – silting in the river through the calculation of  $S_u/S_m$  and the field data, we can plot the relationship between the scour – and – fill intensity in a unit time and  $S_u/S_m$  (see Fig. 2). We can see an obvious trend of the point distribution in Fig. 2, which indicated that during the channel shrinkage process at the reaches from Babu to Laotongzhai in the model, the sediment transport still has the character of “more coming, more silting and more scouring”.



**Fig. 2 Schematic of the relationship between the scour – and – fill intensity and  $S_u/S_m$**

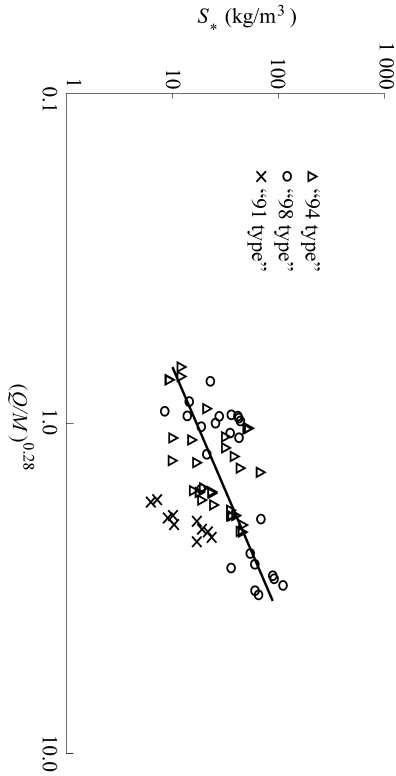
Integrating the Manning Equation and the sediment carrying capacity equation, we can obtain the following expression:

$$S_* \propto \left(\frac{Q}{M}\right)^{0.28} \tag{9}$$

where:  $S_*$  is the sediment carrying capacity,  $Q$  is the discharge,  $M$  is the ratio of perimeter of the wetted area to hydraulic radius. Plotting the relationship of  $S_*$  and  $(Q/M)^{0.28}$  (Fig. 3), we get the follows:

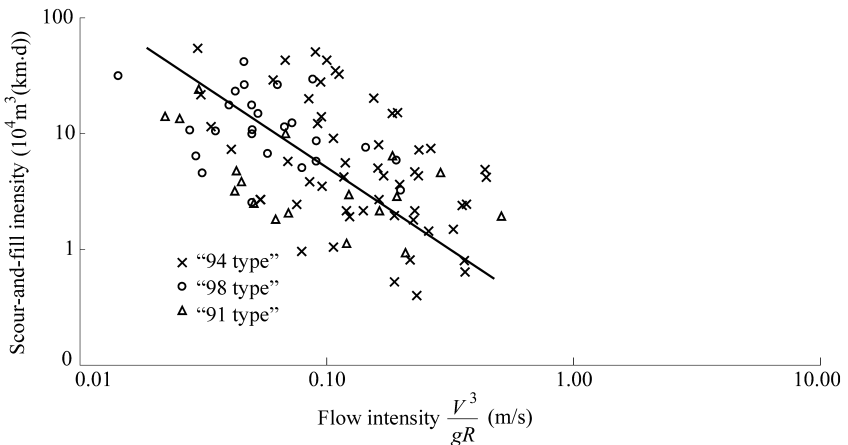
We can see from Fig. 3 that, under the experimental water and sediment conditions, the sediment carrying capacity  $S_*$  and  $(Q/M)^{0.28}$  have a good relationship, no matter what mode of channel shrinkage it is. That is to say, if  $M$  decreases, i. e. the section varies towards narrow and deep during the channel shrinkage process, the sediment carrying capacity will increase, and vice versa. It indicated that the relationship between sediment carrying capacity and main river channel’s morphology is still in accordance with the general riverbed evolution rules.

If we define  $V^3/gR$  as the flow intensity, and plot the relationship of  $V^3/gR$  and the scour – and – silting quantity per day per length in flood season (Fig. 4), we can see that under the experimental water and sediment conditions, the sediment carrying capacity increases with the accretion of the flow intensity, and the scour – and – silting quantity per day per length becomes less and less. It shows that during the channel shrinkage process the bigger flow intensity is more



**Fig. 3** Schematic of the relationship between  $S_*$  and  $(Q/M)^{0.28}$

propitious to alleviate the silting in riverbed. That is to say, the channel shrinkage is reversible, as long as we enhance the flow intensity, we can mitigate the shrinkage extent.



**Fig. 4** Schematic of the relationship between flow intensity and the scour – and – fill quantity per day per length



## 5 Conclusions

According to field data and movable – bed model test, the flood routing characteristics during channel shrinkage process were analyzed to obtain the following conclusions:

(1) No matter how high or low the sediment concentration is, the peak clipping ratio of flood will increase and the flattening – out of flood wave will occur in the channel shrinkage process. However, when the flood peak discharge is close to the bank – full discharge, the flood wave transformation is small and so is the flood peak clipping.

(2) The travel speed of freshet was slowed down and the advance duration was prolonged. When the flood peak discharge is about double of the bank – full discharge, the advance speed of the flood reaches its minimum. Even so, the synchronization adjustment relationship still exists between the average velocity and flux of the channel section.

(3) The channel shrinkage reduced the wetted cross – sectional area, increased the rising speed rate of the average riverbed elevation, and so increased the rising amplitude of flood stage.

(4) After channel shrinkage, the sediment transport by flood still has the feature of “more coming, more silting and more scouring”. Meanwhile, the sediment carrying capacity and have a good proportion relationship between them, which is still in accordance with the general riverbed evolution rules.

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# Analysis of Effects and Countermeasures of Embankment for Agricultural Production on River Training in the Lower Yellow River

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**Abstract:** The Yellow River is a sediment – laden river. Its river course in the lower reaches is very hard to train. Achievements have been gained in river training and safety of flood control has been guaranteed. With inflow becoming low in the lower reaches, ratio of flood peak occurrence decreasing, embankment for agricultural production aggravates sediment silting in the river channel, which produced negative effects on river engineering. The river training strategy “stabilizing the main channel, water and sediment regulation, widening the river and strengthening levee, compensation by policy” should be further carried out. Flood diversion to warp floodplain, strengthening the safety construction of the floodplain, abolishing the embankment for agricultural production should be the emphasis and direction of river training in the lower reaches.

**Key words:** embankment for agricultural production, river training, water and sediment regulation, river channel silting, flood diversion to warp floodplain

## 1 Status quo of river training of the Lower Yellow River

The lower reaches of the Yellow River is 786 km long, which is wide in the upper and narrow in the lower. Gradient is steep in the upper and gentle in the lower. From Baihe to Gaocun, the river is wide with dispersed flows. Mainstream wanders frequently, which is typical wandering reaches. The distance between the dikes on both banks generally is 5 ~ 10 km, of which the widest is over 20 km; the reaches from Gaocun to Taochengpu is the transition from wandering to meandering reaches, whose mainstream tends to be stable through river course training. The distance between the dikes on both banks is 1.4 ~ 8.5 km, most of which is over 5 km. A large number of river training works have been constructed since the foundation of the People’s Republic of China to control the wandering of the mainstream and decreased the frequency of “transverse river, inclining river” occurring and at last ensure the safety of flood control and villages in the floodplain of the Yellow River. Great achievements have been gained in river training. But since 1986, inflow in the lower Yellow River has seriously become less. Flood peak occurs even less. Silting is mainly in the river channel due to the long – term low flows. The silting scope gets fixed with the wandering scope of mainstream under control. Mainstream is silted higher and can not wander, which changes the law of balancing the elevation difference through free wandering of the mainstream of natural wandering river course so that stable mainstream shrinks gradually and flood discharging capacity lowers. Production levee in floodplain promotes the silting in river channel and then forms and pricks up the “secondary suspended river” of “high channel, low floodplain and lower foundation of the levee”. At present, the bankfull discharge decreases from 6,000 m<sup>3</sup>/s to 3,000 m<sup>3</sup>/s. Formed “small flood, high water level and flooding large area” brings heavy pressure to the levee in which there are many hidden weakness and trouble.

## 2 General situation of the production levee of the lower Yellow River

Since 1947, production levee has experienced a developing period of prohibited – encouraged – prohibited. Production levee belongs to peccant buildings. But construction of production levee

could not have been prohibited because of its benefit to the people of the floodplain. 500 km are kept for many years. Since the operation of Xiaolangdi reservoir, more onward parts of production levees have been constructed between river training works, which forms the second and third production levees. After blocking – up the gaps of production levee breaching in Caiji in 2003, some weakness and gaps of production levees were strengthened and enveloped and at the same time, some production levees were built before flood season. The length of production levee only in the reach between Huayuankou and Luohe increased to over 580 km. There are new features;

- ① Length increases obviously. The length of production levees of the lower reaches maintained 510 km from 1980 to 1999. But it increased to 583.753 km in 2004. 68.324 km is increased in the four years.
- ② The distance between both banks of production levee decreases gradually. According to the riverway map of 1/10,000 in 1999, the distance of production levee on both banks above Taochengpu is over 2 ~ 3 km. But the latest investigation showed that the second and third production levees were built before the former ones. The distance between two banks narrows further, being less than 500 m in some reaches.
- ③ Section intension increases gradually. Production levees before 1999 were generally 1.0 – 1.5 m in height, in which very few reached 2.0 m and over 3.0 m was rare. The top of them is mostly 3.0 ~ 5.0 m wide and no necessary to be protected. They have been heightened and widened in recent two years. It is generally 2.0 m high and 4.0 m wide. They are protected by synthesizing material of seepage control and anti – erosion.
- ④ It becomes systematical gradually. Production levees had been asked to remove as building of blocking current for many years. The production levees were off and on. Blocking – up of the gap, extending and development make production systematical and perfect. One or two single production levee reaches 43.4 km long.
- ⑤ Rushing to deal with an emergency and guardianship of production levees are strengthened during flood season. The guardianship of the production levee is regarded as a task by the governments on both banks. They are also guarded by the people.

### 3 Affects of production levee on river training

#### 3.1 Restricting water and sediment exchange of floodplain and channel, making river channel shrinking and more silting in channel

Under natural condition, the floodplain is often flooded in the lower reaches. But affected by roads, ditches, woods and crops, current speed on floodplain is much lower than in channel. Sedimentation rate is quick in floodplain flooding. Primary sedimentation falls in the scope of 500 m outside of beach lip. With becoming deep of flood and large of discharge on floodplain, dikes are formed on its lower parts. More flood and sediment goes into the deep area of the floodplain through the dikes and silts quickly. Clear water after sedimentation runs back to river channel in some suitable spots of the lower reaches, which dilutes and enlarges the current in the channel of the lower reaches. The river channel of the lower reaches is scoured to be deeper, which is good for river course. The non – flooding over the floodplain current silts its sediment only in the river channel. Measured material shows that large floodplain flood makes the floodplain silting high and river channel scouring deep. Small non – floodplain flood only silts its sediment in the river channel. Overall sedimentation in floodplain is larger than in river channel. But the area of the floodplain is larger than river channel. Sedimentation depth is the same both in floodplain and river channel after long term. That is, river channel and floodplain raise in – phase. The elevation of them is not so different, which is good for flood control.

In 1958, the measured largest flood peak of 22,300 m<sup>3</sup>/s occurred at Huayuankou. Sedimentation in the floodplain from Huayuankou to Lijin is 107 million in flood season while 86 million was scoured away in the main channel, which formed high floodplain and deep channel. The medium flood of 7,860 m<sup>3</sup>/s occurred at Huayuankou in 1996. Affected by production levee, some of the floodplain was not flooded. But sedimentation on floodplain in flood season reached 44.5 million. Sediment deposition of 16.1 million t was scoured away in the main channel below

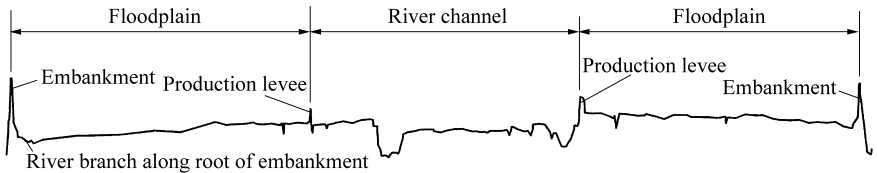
Huayuankou. Thus it can be seen that floodplain flood can mold a main channel good for flood discharging and stable river regime, which is hard to reach through other way.

But production levee blocks flood from flowing over the floodplain (see Table 1), which makes flood restricted at inter - area between production levees on both banks. The rate of flooding floodplain area decreases. Medium and small flood is hard to flood the floodplain. While large flood occurs, sedimentation on floodplain and scouring in main channel is hard to realize because of the people's building and protecting production levee. Sediment exchange between floodplain and channel is restricted, which makes more silting in newly - formed floodplain and river channel. Large area of floodplain could not be flooded and silted for many years. Thus the present secondary suspended river of "high channel, low floodplain and lower foundation of the levee" formed gradually (see Fig. 1). For example, the average elevation of river channel is 1.0 m higher than that of the floodplain while beach lip is 3.0 m higher than the foundation of levee in Dongming reaches.

**Table 1 Statistics of production levee affecting flooding floodplain and silting rate in flood season**

quantity	Typical flood				
	Year of 1953, 1954 1957, 1958	Year of 1966, 1967, 1968	Year of 1975, 1976, 1977	Year of 1981, 1982, 1983, 1985	Year of 1988, 1992, 1994, 1998
Total number of floodplain	8	24	24	32	40
Floodplain affected by production levee	0	2	3	9	20
rate	0	8.33%	12.5%	28.125%	50%

**Note:**Total number of floodplains is the total number of the floodplains which can be inquired about the available material in respective phase.



**Fig. 1 Secondary suspended river of the lower Yellow River**

Silting in river channel is severe. The area of flood flowing of the river channel decreases. Main river channel shrinks. The difference of the elevation of floodplain and riverbed becomes small. Bankfull discharge of river course lowers gradually(see Table 2).

At the same time, the main channel content decreases gradually. The main channel capacity under the water level of designed flood control in the reach from Tiexie to the estuary was 479 million  $m^3$  in 1992, which is equal to 83.76% of 572 million  $m^3$  in 1986. Main channel capacity changing under the bankfull discharge level in typical years see Table 3.

### 3.2 Side effects of production levee on flood control works in river course

Production levee affects the safety of levee and flood control works;

(1) Effects on the safety of dikes

Historic experience tells us the following: river does not run along the levee for quite a long time where production levee exists. The levee is not often tested by flood. Once large flood occurs,

**Table 2 Change of bankfull discharge in typical years Unit: m<sup>3</sup>/s**

Item	Huayuankou	Jiahetan	Gaocun	Sunkou
After flood season in 1958	8,000	10,000	10,000	9,800
After flood season in 1964	9,000	11,500	11,000	8,500
After flood season in 1973	3,500	3,200	3,500	3,700
After flood season in 1980	4,400	5,300	4,300	4,700
After flood season in 1985	6,900	7,000	6,900	6,500
After flood season in 1997	3,900	3,800	3,000	3,100
before flood season in 2002	4,100	2,880	1,960	2,070

production levees burst. Flood rushes directly to the levee, which is very dangerous. For example, breaching in Simingtian, Lankao county in 1933 and Dongzhuang, Juancheng county in 1935 all caused bursting of production levee. Therefore, the danger of production levee was known early. For example, Yellow River Shandong Bureau asked Shandong Government to prevent the people from building production levee in 1933: "The people build production levee near the river to circle floodplain for planting crops. Once flood occurs, the current would flow along the foundation of the levee to threaten the safety of the levee because the river is too narrow to contain the flood. Building production levee should be prohibited for the safety of the river." It is hard for current to enter and recede from the floodplain because of the building of production levee so that production levee blocks clear water moving back to river channel. Seeper stays at the foundation of the levee which was dipping in water for a long time. Seeping, piping, splitting, collapsing, leakage, etc. cause dangers and increases the possibility of dikes' bursting. Flood disaster in autumn, 2003 in Lankao and Dongming counties proved it.

#### (2) Effects on the safety of river training works

At present, river training works are built according to river training line scientifically marked out. It is used to control and guide river regime, protect land and villages from rushing and eroding. Production levee was built in random, which usually violates the evolving law of river course. Quite a lot of production levees were built in the main river channel, which seriously disturbs the normal and rational flow way. It affects the role - playing of river training works and usually causes danger. For example, during the flood in September, 1996, the current rushes directly to Number 6,7,8,9 groins of Hanhutong river training works because of the production levees in the upstream and opposite bank, where persistently rushing and scouring by high flow damaged the four groins in a very short time.

### 3.3 Effect analysis on improving sediment - discharging into the sea

Results calculated by river mathematical model shows: successive production levee of 4,000 m<sup>3</sup>/s can effectively restrict small flood flowing in the river channel, which reduces the moving of large and medium flood in a floodplain and accelerates current speed in the river channel. Sediment - discharging power of river channel remains stronger to promote scouring riverbed or decreasing

Table 3 Main channel capacity changing under the bankfull discharge level in typical years

year		1958		1968		1977		1982		1992		1996		1998	
section	distance (km)	area (m <sup>2</sup> )	Water quantity (thousand m <sup>3</sup> )	area (m <sup>2</sup> )	Water quantity (thousand m <sup>3</sup> )	area (m <sup>2</sup> )	Water quantity (thousand m <sup>3</sup> )	area (m <sup>2</sup> )	Water quantity (thousand m <sup>3</sup> )	area (m <sup>2</sup> )	Water quantity (thousand m <sup>3</sup> )	area (m <sup>2</sup> )	Water quantity (thousand m <sup>3</sup> )	area (m <sup>2</sup> )	Water quantity (thousand m <sup>3</sup> )
Huayankou	18.46	3,118	733.5	11,178	1,188.35	5,929	484.4	4,550	487.15	5,524	537.1	1,033	134.75	1,690	155.95
Laitongzhai	29.94	11,552	702.2	12,589	7,912.000	3,759	875.65	5,193	883.7	5,218	817.2	1,662	223.95	1,429	205.75
Heishi	18.5	2,492	1,045.05	3,235	4,439.000	13,754	950.1	12,481	735.05	11,126	712.7	2,817	172.05	2,686	198.9
Liuyankou	28.12	18,409	966.5	5,643	1,011.75	5,248	822.1	2,220	607.0	3,128	637.4	624	78.6	1,292	125.9
Caogang	12.98	921	223.05	14,592	2,131.8	11,194	1,894.1	9,920	1,595.05	9,620	1,549.8	948	412.15	1,226	361.5
Jiahetan	15.22	3,540		28,044	1,803.95	26,688	1,463.6	21,981	1,199.95	21,376	1,228.4	7,295	473.7	6,004	377.25
Chanfang	11.29			8,035	747.75	2,584	309.55	2,018	204.85	3,196	193.95	2,179	365.05	1,541	100.2
Youfangzhai	30.62			6,902	692.8	3,607	316.1	2,079	221.85	687	92.75	5,122	266.95	463	49.45
yagnziaoizhai	16.44	6,540		6,936	472.0	2,715	205.0	2,346	141.9	1,168	88.35	217	24.75	526	38.2
hedao	18.27			2,504	283.45	1,385	160.25	492	72.35	599	64.85	278	31.75	238	35.5
Nanxiaodi	23.75			4,165	270.45	1,820	170.1	955	93.25	698	69.5	357	56.9	472	68.05
Susizhuang	40.09			2,244	210.35	1,582	195.4	910	134.45	692	120.1	781	86.4	889	95.25
Shilou	11.47			1,963	250.3	2,326	258.7	1,779	196.35	1,710	164.7	947	88.1	1,016	73.65
Xumatou	20.57			3,043	421.95	2,848	272.15	2,148	216.85	1,584	184.2	815	90.45	457	90.05
Yangzhai				5,396		2,595		2,189		2,100		994		1,344	
Water quantity total (10 <sup>8</sup> m <sup>3</sup> )					1.072		0.837,7		0.678,9		0.646,1		0.250,6		0.197,6

sedimentation. If flood flows into the floodplain without production levee, sediment – discharging power lowers and silts more in riverbed. Existing production levee is not successive or very easy to be broken and flood flows often through the gap of production levee, which reduces the power of sediment – discharging of the current.

But the effect is finite and conditional. When flood is larger and production levee breaches, the effect decreases largely; the distance between the production levees on both banks is generally 1 ~ 3 km, which is much wider than the required width of 500 ~ 600 m during which no silting in the lower Yellow River reaches. River channel is wide and shallow. Wandering river channel without flooding floodplain remains more silting and less scouring.

#### 4 Analysis of countermeasures

Based on above knowledge, the strategy of “stabilizing the main channel, water and sediment regulation, strengthening dikes with wide river and compensation by policy” should be taken in short – term river training of the lower reaches.

(1) Sediment issue will exist for a long term. Silting in the river channel of the lower reaches is inevitable. Flood control to ensure safety is still our main task in the future river training. With the operating of Xiaolangdi reservoir, medium and small floods caused by water and sediment regulation to transport sediment into the sea are predominated in the lower reaches. Therefore, it is suggested that on the basis of summarizing and analyzing the experience and law of river training of medium flood, the latest four times of water and sediment regulation, the steps of wandering river reaches training works construction should be quickened taking medium water way as the aim. River training of small flood should be carried out to make up and perfect river training works system of the lower reaches; water and sediment regulating and controlling system should be set up and perfected. Water and sediment regulation should be unremitting. Bankfull discharge of the lower reaches should be heightened to mold and maintain the narrow and deep river channel with medium flood flow of 5,000 m<sup>3</sup>/s. In the end, stable main river channel good for flood controlling and sediment discharging will be molded to create condition for doing away with production levee completely.

With the advancing of training and developing of the Yellow River, conversion from controlling flood to utilizing flood and molding flood will be realized. It is suggested that managing floodplain in zones in the lower reaches. The function would be brought into play of flood detention, sediment warping, flood releasing and fostering population, etc. . Township in floodplain should be built for people living safely and agricultural byproduct processing. Crop – planting zone which can be flooded by medium flood should be set up. Low herd – raising floodplain zone which can be flooded by small flood would remain. We should sum up the experience and learn the lessons of production levee and putting gap beforehand in the production levee. Flood diversion gate for warping should be set up in the middle suitable spot of controlling and guiding works. Flood diversion to warp floodplain should be positively carried out to train “secondary suspended river” as soon as possible.

(2) Based on long – term flood control of the lower reaches after the construction of Xiaolangdi reservoir and primarily – formed works system of flood control and sedimentation decreasing, flood detention, sediment deposition and flood diversion functions of floodplain should be brought into play as much as possible according to the scheme of strengthening dikes in wide river. The construction of standardized levee should be quickened. Administration of all levels of the Yellow River should make and renew severe compulsive restriction in river course management and operation according to flood control programming and floodplain construction programming of the lower reaches. Safety construction of floodplain should be strengthened. Compensation mechanism for flooding floodplain should be set up and perfected as soon as possible. Production levee before river training works should be abolished as soon as we can.

#### 5 Conclusions

After the operation of Xiaolangdi reservoir, grades of flood into the lower reaches are obviously

polarized. At other times, floods into the lower reaches are mainly small. Once large flood occurs, human being could not control it at all. The Yellow River is still a sediment – laden river. Flood control is hard and the river training in the lower reaches is still difficult. Flood control safety should be guaranteed. Safety of the people in the floodplain and sustainable development should be ensured to some degree. Training strategy of “stabilizing main channel, water and sediment regulation, strengthening dikes in wide river and compensation by policy” should be stuck to. The side effects of production levee should be dealt with in reasoning way to realize the harmony of human being and nature.



## Thinking about the Effects of Sediment Deposition on Flood Control of the Yellow River

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**Abstract:** Safety and flood control of the Yellow River is an affair which the Communist Party and the State have been concerned. With the development and utilization of the Yellow River water resources in large range, the ratio of water and sediment inflow in the lower reaches is more out of line. Especially, the water inflow is severely low and the frequency and grade of the flood decrease in the lower reach of Yellow River. Large amount of sediment silts in the river channel every year while flood control system becomes better. River channel shrinking and flood control engineering works standard reducing caused by silting should arouse our pondering and recognizing. Measures, such as water and sediment regulation, flood diversion for warping, etc., should be taken to solve the problem.

**Key words:** flood defence, silting, the Yellow River

The safety of the Yellow River flood control attracts the attention of earthling. To guarantee the safety of the Yellow River flood control and ensure no breaching at Huayuankou when flood discharge is 22,300 m<sup>3</sup>/s, the state funds great to systematically father the Yellow River lower reaches since the foundation of the People's Republic of China. Safety for nearly 60 years in the Yellow River flood control has been achieved. The new situation of "small discharge with high water level", "small flood with large area inundating", etc. frequently appears in recent over ten years in the lower reaches of the Yellow River, which makes people have new understanding on the silting disaster. Thinking about silting effects on the Yellow River flood control is briefing in this article.

### 1 Flood control objects and its main measures of the lower reaches

The task of flood control is arduous. Water and sediment relationship is complicated. Flood situation is constantly changing. Flood control headquarters of all levels should have preparation and measures for emergency action. The object of flood control of the Yellow River is: no levee breaching should be ensured at Huayuankou when the flood discharge is 22,000 m<sup>3</sup>/s and below. Once over-standard flood is coming, we should get ready and have countermeasures and try our best to reduce the disaster; the safety of the water course controlling and guiding engineering in the designed standard should be ensured; emigration to avoid flood in floodplain and flood detention area should be done well in time to ensure the safety of the people there and decrease the loss of flood disaster.

Flood control engineering system of "reaining water on the upper reaches, discharging water at lower reaches and retarding water in the water detention areas along both banks" has been constructed in the lower Yellow River to guarantee the safety of the Yellow River flood control. The system mainly consists of reservoirs, levees and river course training engineering on the main stem. The engineering of blocking in the upper includes reservoirs on the mainstream, such as Xiaolangdi reservoir, Sanmenxia reservoir, etc.; 22 reservoirs have been built on the upper and middle reaches of the Yellow River in the last over 50 years. The overall storage of them is 61.7 billion m<sup>3</sup>, which exceeded the yearly average runoff of the Yellow River. Controlling capacity on flood becomes stronger. Water diversion caused by population increasing and economic development becomes more. Flood occurring in the lower reaches grows less. In 1950s, average occurring discharge of 4,000 m<sup>3</sup>/s and over it is 6.3 events. In 1960s~1980s, it is 3.6 events. In 1990s, it is 0.9 events. In 21st century, no flood discharge is over 4,000 m<sup>3</sup>/s; engineering structures of releasing

to the lower includes levees on both banks, vulnerable spots and river course training works; detention areas refer to Dongping lake, Beijindi flood detention area along the lower reaches.

At the same times, tri – unity joint defense system and flood control organization at five levels: province, city, county, township and village were founded.

## 2 Definition of flood and sediment disaster

River is a dynamic feedback system, which takes sediment as resonance. Current and riverbed interact on each other. Local water and sand changing will cause the change of sediment discharging, which will cause adjustment of larger scope. Among these effects, causing and aggravating of flood disaster is the most and the most direct threat to human beings. ; sediment disaster has accumulating effect owing to water and soil erosion serious in the upper reaches. The phenomenon of aggravating river's flood and sediment disaster caused by sediment discharging becomes more serious. Therefore, the definition of sediment disaster is: sediment causes disaster or sediment – caused other carrier does harm to the human – existing environment and civilization construction, or brings loss to economy, which is called sediment disaster. Sediment – caused disaster is called direct disaster, such as slide, mud flow, collapse, etc. ; disaster induced by sediment – caused other carrier is called indirect disaster. For example, sediment from soil erosion silting in river channel or reservoir year by year makes riverbed rise. Flood discharge capacity becomes lower. Not so large flood could cause disasters such as brimming over embankment, intruding, etc.

Flood and sediment disaster is not a new disaster, which is the subsystem between flood disaster and sediment disaster. In previous disaster study, some flood and sediment disasters were attributed to flood disaster while others were attributed to sediment disaster, which dis severed the relationship between them so that the frequent appearance of “small water discharge, high water level” in recent years is unable to be explained.

## 3 Newly – arisen situation in flood control in the Lower Yellow River in last several years

In recent years, newly – arisen situation in flood control in the lower Yellow River is that flood is not so large, but flood control pressure is heavy. Large flood caused heavy disaster in old days. But now large and small flood causes heavy disaster. The most obvious features are:

(1) The phenomenon of small water discharge, high water level, heavy imperiling and big loss becomes aggravating year by year. The discharge of the flood at Huayuankou in 1996 was only one third of that in 1958 but water level was 1.0 m higher than that in 1958. Many places were in danger. Over 1,000 thousand people in more than 40 counties and cities of Shandong and Henan Provinces were affected by flood. During the first time water and sediment regulation of Xiaolangdi reservoir in July, 2002, water level in Gaocun hydrological station when the discharge is 2,930  $\text{m}^3/\text{s}$  is 0.55 m higher than the water level in the same discharge in August, 1996; over flowing on floodplain occurred when the discharge is less than 2,000  $\text{m}^3/\text{s}$  in the floodplain of Puyang between the upper and lower of Gaocun. The current rushed directly to the levee and ran along it. The water in Puyang section is 4 ~ 5 m deep near the levee. The safety of the levee is threatened.

(2) Large area, large scope affected by flood is the other feature of flood disaster in recent years. The last several years are dry year. Main river channel shrank in the lower reaches. Bankfull discharge decreased. The superelevation between riverbed and floodplain lowered. “Secondary suspended river” of “high riverbed, low floodplain and low – lying foundation of the levee” pricked up. If the same bankfull discharge was past before, the large area and large scope of floodplain would be flowed now. In August, 1996, flood peak is only 6,260  $\text{m}^3/\text{s}$ , but water level is very high causing serious flood disaster in the lower reaches. 76 thousand ha. of cropland were flooded. 67 villages leaned close to water or soaked in water; irrigation works, traffic line, communication line, etc. shattered seriously; and Direct economic loss is about 0.215 billion yuan. The high floodplain formed in 1855, which was not flooded in 1958 and 1982, leaned close to water in 2006. The 16

thousand ha. of cropland was flooded. 38 villages soaked in water and besieged by water. Since 1999, no flood has occurred. Abnormal river bend formed in Zhangzhuang reaches between Jiahetan and Guantai so that the houses of three farmers collapsed into the river. The situation remains up to now. Water and sediment regulation started from July 4, 2002. The discharge at Gaocun is 2,280 m<sup>3</sup>/s on July 7. At 11:30 in the morning, the embankment of Wanzhai canal in Xicheng floodplain, Puyang County breached. Whole Xicheng floodplain was flooded. Water quantity into the floodplain is 313.06 million m<sup>3</sup>. The discharge of that floodplain is 357 m<sup>3</sup>/s. Average water depth is 1.5 m. The deepest is 2.5 m. Flooded area reaches 15 thousand ha. The number of water – besieged villages is 133 with population of 83,830. Other affected villages are 37 with population 30,190. On September 18, 2003, the production embankments in Caiji village, Guying township, Lankao County, Henan Province were breached, which caused the floodplain in the north of Lankao County and Dongming floodplain flooded. Average water depth is 2.9 m. The deepest reached 5m. The area of 18.5 thousand ha. was flooded, which included 16.8 thousand ha. cropland and 152 villages of Guying township, Jiaoyuan township and Changxing township with 114.2 thousand people were besieged by water. 32.1 thousand of people were evacuated; 36,191 rooms of 9,738 farmers were shattered. ; and 4,252 rooms of 1,733 farmers toppled down.

(3) Large danger while small flood occurring is an obvious feature of river channel training engineering in danger in recent years. River channel training project has gradually been matched. Changing of river regime has also gradually been brought under control. Abnormal river regime develops quickly in the scope of works controlling due to river channel shrinking. Transverse river, inclining river in a small scope occurred now and then. Groins and dykes were in danger because flood lasts long. Even heavy danger occurred time and again. For example, in September, 1993, transverse river formed facing Heigangkou when the water discharge was only 1,000 m<sup>3</sup>/s. The transverse river rushed directly to the 840 m – long place between Number 63 groin and Gaozhuzhuang. The floodplain collapsed for 600 m. Mainstream is only 64 m from the levee. It directly threatened the safety of the levee of the Yellow River. Through rushing to repair 8 groins by over 2000 army corps and civilian day and night, the safety of the levee was guaranteed. At 5:00 of September 10, 2003, water discharge of the mainstream is 1,500 m<sup>3</sup>/s. The large swift current rushed to Number 14 ~ 17 and the backwater cleaned out the near bank. Surface stone sank and the soil cracked. The cubage in danger is 992 m<sup>3</sup>.

#### 4 Analysis of silting effect on the Yellow River flood control

River is a dynamic feedback system, which takes sediment as resonance. Current and riverbed interact on each other. Local water and sand changing will cause the change of sediment transport, which will cause adjustment of larger scope along the river. Small flood causes huge disaster year by year. The frequency of disaster increases, which seriously affects the flood control. Direct reason of worsening flood control in natural factors is sediment disaster besides there still exist deficiencies of the effects of human activities and consciousness, flood control management and flood control works construction. Its most obvious representation is silting.

##### 4.1 River channel shrinking and flood carrying capacity reducing

Sediment in the lower reaches of the Yellow River is mainly transported into the sea, makes land in the estuary and silts in the river course. Only small part of it is piped to the irrigating area or to strengthen the embankment. Sediment concentrates on silting in the main river channel because no large flood occurred in many years. The silting proportion of the main channel of the river increased from 30% in 1980s to 70%. At present, transverse gradient below Dongbatou reaches 1‰ ~ 2‰ while longitudinal gradient is 0.14‰. Once larger flood occurs, transverse river, inclining river even “rolling river” are very easy to be formed. Then the river flows along the levee, which threatens the safety of the levee. The flow discharging capacity of the river channel decreases obviously. The floodplain would be flooded in part reaches when the water discharge is only 2,000

$\text{m}^3/\text{s}$ . Small flood would lead to huge disaster.

#### 4.2 Flood control standard lowering

So we can deduce that the embankment of the Yellow River takes  $22,300 \text{ m}^3/\text{s}$  at Huayuankou as the designed flood control standard. Water level of the flood higher than normal flood water level would lead to flood control standard of the embankment lowered.

Designed flood control water level is the main indicator of flood control standard of the buildings in river channel. Whether the top of the buildings in river channel exceeds designed water level or not directly shows whether the buildings are on safe side or not. Silting in the river channel causes riverbed rising and decreases the channel capacity and flood carrying capacity of the river, which makes water level rising at the comparative discharge and defending standard of the levee relatively lowered. For example, high sand – laden flood in August, 1992 caused serious silting in river course, which made water level at Huayuankou reaching  $94.33 \text{ m}$  when the runoff is  $6,260 \text{ m}^3/\text{s}$ . It is the same as the water level of the past common flood of  $12,000 \text{ m}^3/\text{s}$ . Penetrating dangers such as soaking, piping, etc. occurred in many places, which appeared only in past large flood. The highest water level at Huayuankou is  $94.73 \text{ m}$  when the flood peak is  $7,860 \text{ m}^3/\text{s}$  in August, 1996. It is the highest water level recorded at this station. It is  $0.74 \text{ m}$  higher than the water level of  $93.99 \text{ m}$  when the flood peak is  $15,300 \text{ m}^3/\text{s}$  in August, 1982.

While the risk of flood increases, silting makes flood progressing retardant, which makes flood last longer. For example, in 1950s and 1960s, flood running from Huayuankou to the sea spent 7 days, but it spent 13 days in August, 1992 and 18 days in August, 1996.

#### 4.3 Flood occurring frequency increasing

The lower Yellow River levee construction takes flood discharge of  $22,300 \text{ m}^3/\text{s}$  at Huayuankou as the defense standard. Preparation and measures of flood control is made and taken according to water level at all levels to guarantee the safety of flood control. The model based on normal relationship between flood water level and discharge is right. Due to the silting in river course, the relationship between flood water level and discharge becomes abnormal, which made water level unconventionally high. The high water level which usually occurred by large flood is emerged even if it is small discharge of flood. The danger of soaking, flooding the floodplain, etc occurs more. Silting makes high water level of the flood occurring more frequently. River training works becomes in danger in small flood, which only occurred in large discharge of flood before. For example, the discharge of flood in August in 1992 and flood in August 1996 are respectively  $6,260 \text{ m}^3/\text{s}$  and  $7,860 \text{ m}^3/\text{s}$ . They should occur once in 5 years through calculation according to the flood discharge. But the water levels were equivalent to the water level of  $12,000 \text{ m}^3/\text{s}$ , which occurs only once in 100 years. That is to say, the flood of  $12,000 \text{ m}^3/\text{s}$  which occurred once in 100 years becomes once in 5 years now because of silting.

### 5 Countermeasures and suggestions

In order to decrease the disadvantage of silting to flood control, the training strategy of “stabilizing main channel, water and sediment regulation, wide river and strengthening the embankment, compensation by policy” should be taken in the short – term training of the river course of the lower Yellow River.

Sediment problem exists for a long term. Silting is inevitable in the lower reaches. Flood control of the Yellow River is still important in the future. Therefore, it is suggested to further summarize and analyze the experience of small and middle – sized river channel regulation, experience and rules of the last four times of water and sediment regulations. The steps of river course training of wandering river reaches should be quickened to stabilize the way of middle flow and reduce silting in river course. River channel of small water training should be carried out to

complement and perfect the system of river course training works in the lower Yellow River; water and sediment regulation system should be set up and consummated. Water and sediment regulation should be unremitting to enlarge the bankfull discharge of the lower reaches. Narrow and deep river channel of medium flow at discharge of  $5,000 \text{ m}^3/\text{s}$  should be molded and maintained in order to stabilize and mold the main channel in favor of flood control and sediment release; standardized embankment construction would be promoted according to the strategy of "wide river and strengthening embankment" to decrease the disadvantages of small flood, high water level to flood control in order to ensure the safety of flood control.

With the advancing of training and developing of the Yellow River, conversion from flood controlling to managing, utilizing and molding flood will be realized. It is suggested that managing floodplain in dividing into sections in the lower reaches. The function would be brought into play of flood detention, sediment warping, flood releasing and fostering population, etc. Township in floodplain should be built for people living safely and agricultural byproduct processing. Crop - planting zone which can be flooded by medium flood should be set up. Low herd - raising floodplain zone which can be flooded by small flood would remain. We should actively strive for compensation policy for flood detention zone and sediment warping area. We should positively carry out flood diversion to warp floodplain in suitable occasion to training "secondary suspended river" in order to realize harmonized living together of human being and flood with each other.

Whereas the serious rising of flood water level causing by silting, the flood discharge can not show flood control standard of the constructions in river course. We should set up flood control water level system using the water level of flood control, floodplain water level, etc. as main signs.

## 6 Conclusions

Small discharge, high water level caused by silting affects flood control, which quickens the frequency of large flood occurring in certain degree. We should set up flood control water level system using flood control water level, floodplain water level, etc. as main signs. Training strategy of "stabilizing main channel, water and sediment regulation, wide river and strengthening the embankment and compensation by policy" in the lower reaches should insist on. Flood diversion to release sediment and training "secondary suspended river" should be done to ensure the safety of flood control of the Yellow River.

# Exploration of the Technique “Detaining the Coarse and Discharging the Fine” for Warping Dam

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**Abstract:** An important approach to ‘Sustaining the Healthy Life of the Yellow River’ is to reduce sediment, especially reduce coarse sediment. The warping dams built in the middle reaches of the Yellow River have retained a great quantity of sediment over the years. However, they were all designed on the ideology, “Intercepting and Retaining All Sediment”, without allowance for the size – grade distribution of the sediment retained, so trapping a mass of fine sediment. Therefore, when calculating the sediment – retaining benefit of warping dam, only 1/4 of total sediment retention was taken into account, greatly reducing the sediment retaining effect of warping dam on sediment reduction in Yellow River.

**Key words:** warping dam, sediment, sediment retaining benefit, detaining the Coarse and Discharging the Fine, Loess Plateau

## 1 Introduction

Studies have shown that great part of the sediment depositing in the lower reaches of Yellow River is coarse sediment with the grain size of more than 0.05 mm. Those fine sediments with the grain size of less than 0.05 mm could be discharged to the sea along with water flow. The heavy and coarse sediment areas in the middle reaches of Yellow River is main sediment contribution region. Hydrological observation data shows that the sediment with the grain size of less than 0.05mm accounts for about 50% of total sediment even in coarse sediment concentrated region. Therefore, it is essential to study the measures for effectively dealing with (intercept and detain) coarse sediment coming from coarse sediment concentrated region. This paper explores the technique, “Detaining the coarse and Discharging the fine”, for the operation mode of warping dam on the basis of preexisting study results and in combination with the examples of warping dam design, and presents the recommendations to the dam design to increase sediment retention benefit, so that warping dams can play a greater role in “Sustaining the Healthy Life of the Yellow River”.

## 1 Law of coarse sediment movement

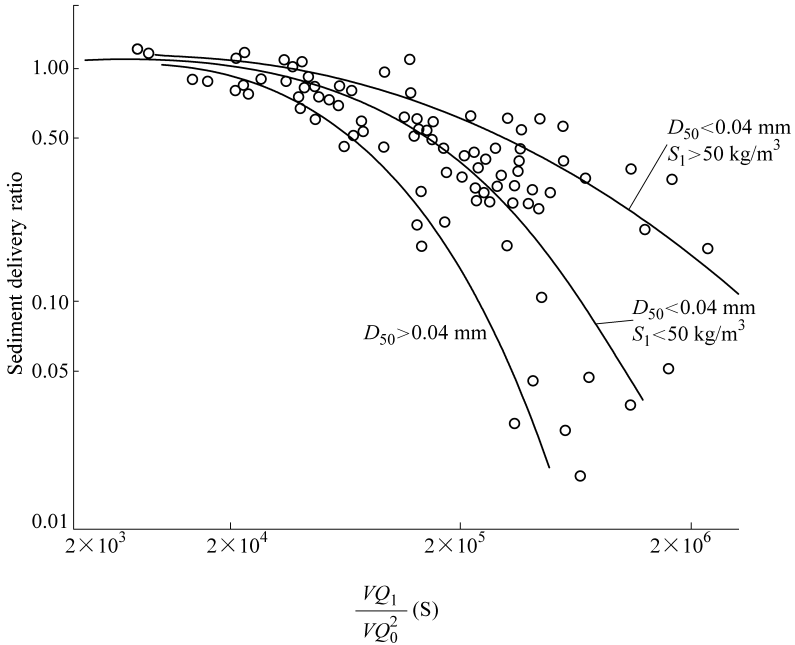
According to the studies, highly concentrated silt discharge will come into being when sediment concentration reaches 200 ~ 250 kg/m<sup>3</sup> or more. Substantial existence of solid grains in hyperconcentration flow greatly increases the viscosity of turbid suspension. Tests and studies show that for the suspension with the sediment concentration of 300 kg/m<sup>3</sup>, its viscosity is 2.5 ~ 3.5 times of clear water at the same temperature. When sediment concentration reaches 600 kg/m<sup>3</sup>, its viscosity will be at least 5 times of clear water at the same temperature. This will lead to significant change of the fluid flow in nature. Flow resistance, falling velocity of grains in the fluid flow and sediment carrying capacity will greatly differ with clear water. (Table 1).

The studies show that highly concentrated silt discharge can change the size – grade distribution of reservoir outflow sediment. Following graph (Fig. 1) presents the relation between sediment delivery ratio and reservoir/sediment characteristics in a flood of some reservoirs in our country. Where,  $V$  is reservoir storage;  $Q_1$  and  $Q_0$  are reservoir inflow and outflow respectively. Horizontal ordinate,  $VQ_i/Q_0^2$ , has the unit of time, meaning the time of a flood staying in reservoir. Besides, sediment delivery ratio of a reservoir is also related to sediment size and concentration. Fine

sediment can be discharged out of reservoir more easily than coarse sediment. When sediment concentration exceeds  $50 \text{ kg/m}^3$ , sediment falling velocity will reduce. At the same time, sediment delivery ratio of a reservoir increase.

**Table 1** Falling velocity and average falling velocity of graded sediment in hyperconcentration flow

$d_i$ (mm)	0.35	0.158	0.087	0.061	0.035	0.016	0.008	0.004,6	$\Sigma$
$\omega_i$ (cm/s)	1.676	0.567	0.172	0.084	0.028	0.005,8	0.001,5	0.000,5	
$\Delta p_i$	0.015	0.148	0.157	0.205	0.218	0.113	0.02	0.054	1.0
$\Delta p_i \omega_i$	0.025	0.084	0.027	0.017,2	0.006,1	0.000,7	0	0	0.16



**Fig. 1** Relationship between sediment delivey ratio and sediment characteristics

The study of hyperconcentration flow characteristics allows us to understand better the state of sediment movement in warping dam.

(1) The floods in small watershed, particularly in heavy and coarse sediment region, are normally of highly concentrated silt discharge. Before coming into reservoirs, the floods are turbulent flow, entraining a large quantity of sediment. After coming into reservoirs, the floods slow down, and move toward the dams slowly.

(2) Before the floods come into reservoirs completely, reservoir water level ascends gradually. At this time, reservoir outflow normally has the same sediment concentration and gradation as previous state.

(3) After the floods come into reservoirs completely, their flow velocity is nearly zero. Sediments settle down substantially. However, for highly concentrated silt discharge, fine sediments fall much faster than coarse sediments. As per the calculation using Table 1 data, coarse sediments settle down completely several hours after the floods coming into reservoirs, while fine sediments settle - down needs at least 10 hours.

## 2 Preliminary demonstration of “detaining the coarse and discharging the fine” for warping dam

With the development of warping dam design technique and the improvement of economic strength, their design and operation can be carried out in a better way to achieve the target, “Detaining the Coarse and Discharging the Fine”, so as to build farmland by colmatage and increase sediment – reducing benefit for Yellow River.

### 2.1 Sediment yield of yellow river main branches

The floods coming from the heavy and coarse sediment areas in the middle reaches of the Yellow River are largely of highly concentrated silt discharge. Average sediment concentration, obtained by dividing total sediment in flood season by total runoff, normally exceeds  $400 \text{ kg/m}^3$ . Moreover, main tributaries in the middle reaches of Yellow River are not only of highly concentrated silt discharge frequently, but have higher coarse sediment concentration (Table 2). Statistical data of individual tributaries in the table shows that 80% of the floods have the sediment concentration of more than  $500 \text{ kg/m}^3$ . Particularly, Huangfu River and Kuye River basins are characterized by extremely coarse loess, where 244 floods have the sediment concentration of more than  $1,000 \text{ kg/m}^3$ .

**Table 2 Sediment yield of Yellow River main branches**

Source Region	Tributary	Hydrological Station	Drainage Area ( $\text{km}^2$ )	Sediment Yielding Modulus ( $\text{t}/(\text{km}^2 \cdot \text{a})$ )	$d_{50}$ (mm)	$P > 0.05$ (%)	$S_{\text{max}}$ ( $\text{kg}/\text{m}^3$ )	Year
Coarse sediment area	Huangpu River	Huangfu	3,199	18,060	0.079	58	1,570	1974
	Gushan River	Gaoshiya	1,263	22,130	0.046	46	1,300	1976
	Kuyehe River	Wenjiachuan	8,645	15,270	0.069	56	1,500	1964
	Tuweihe River	Gaojiachuan	3,253	9,880	0.069	61	1,410	
	Jialuhe River	Shenjiawan	1,121	24,980	0.045	44	1,480	1963
	Wudinghe River	Chuankou	30,217	5,270	0.040	37	1,290	1966
	Dalihe River	Suide	3,893	16,300			1,420	1964
	Beiluohu River	Zhuangtou	25,154	3,810	0.030	22	1,190	1950
Fine sediment area	Jinghe River	Zhangjiashan	43,216	5,920	0.025	20	1,040	1963
	Jinghe River	Yangjiaping	14,214	6,690			900	1979
	Weihe River	Xianyang	16,827	4,060	0.015	13	729	1968
	Weihe River	Nanhechuan	23,385	6,160			953	1959
	Pu River	Maojiahe	7,190	6,580			992	1965
	Fenhe River	Lancun	7,705	1,860			544	1973
	Fenhe River	Yitang	23,925	597	0.018	17	731	1953
	Jinghe River	Jingchuan	3,145	6,010			762	1973

### 2.2 Sediment modulus of both total sediment and coarse sediment should be taken into consideration in the design of warping dam

In order to achieve the target of “Detaining the Coarse and Discharging the Fine”, the design of warping dam should be based on such an ideology that intercept and retain most of coarse sediment; and discharge most of fine sediment.

In the 1.6 billion tons sediments coming to the lower reaches of the Yellow River, there are



0.364 billion tons coarse sediments, accounting for 22.75% of total sediments. Heavy and coarse sediment areas contribute 1.182 billion tons sediments to the Yellow River each year, accounting for 73.88% of total sediment runoff, of which, there are 0.319 billion tons coarse sediments with the grain size of greater than 0.05 mm, accounting for 87.64% of total coarse sediment runoff. No doubt, intercepting and retaining this part of sediments, especially coarse sediments, in the numerous gullies and ravines in the middle reaches of Yellow River is of great significance to the control and regulation of Yellow River. Considering the conditional restriction of building dams in the middle reaches of Yellow River and national investment level, the planning and design of warping dam should be based on such a principle in future that retain as much coarse sediment as possible using a limited amount of warping dams.

Therefore, coarse sediment runoff modulus should be taken into account when calculating the sediment retention capacity of warping dam, as follows:

$$V = M_0 \times S \times T / D = M \times R \times S \times T / D$$

where,  $V$  is Sediment retention capacity,  $10^4 \text{ m}^3$ ;  $M_0$  is coarse sediment runoff modulus,  $10^4 \text{ t/km}^2$ ;  $S$  is Area of the land under the control of dam,  $\text{km}^2$ ;  $T$  is Sedimentation service life, years;  $D$  is Specific gravity of sediment,  $\text{t/m}^3$ , generally to take 1.35;  $M$  is Soil erosion modulus,  $10^4 \text{ t/km}^2$ ;  $R$  is Percent of coarse sediment, %.

### 2.3 Both ordinary flood and designed flood should be taken into consideration in the design of water outlet works

The floods in the middle reaches of Yellow River are characterized by “Great runoff and Great sediment” and “Great runoff and Coarse sediment”. Sometimes, the amount of sediment carried by a flood takes up over 60% of yearly sediment runoff. Therefore, attaching importance to the design flood discharge of warping dam is of great value to achieving the target, “Detaining the Coarse and Discharging the Fine”.

On the other hand, ordinary flood carries 40% of yearly incoming sediment. Therefore, “Detaining the Coarse and Discharging the Fine” should also be taken into account for ordinary flood to avoid “Storing the muddy and Releasing the clear” at the time of ordinary flood.

### 2.4 Increase the flood discharge of outlet works so as to reduce flood detention time and discharge fine sediment out of reservoir

As per Table 1, in hyperconcentration flow, the deposition rate of coarse sediment is above 1 m/h (grain size, 0.035 mm; 101 cm/h; 0.061 mm; 302 cm/h). Normally, they can settle down completely within several hours. The deposition rate of fine sediment is much less than 1m/h (grain size, 0.016 mm; 21 cm/h). Complete sedimentation needs longer time. The design of outlet works can be optimized according to this characteristic that there is a greater difference in the rate of deposition between fine and coarse sediments so as to achieve the target, “Detaining the Coarse and Discharging the Fine”.

First of all, increase outlet diameter as appropriate to augment discharge capacity. To achieve the target, “Detaining the Coarse and Discharging the Fine”. It is generally required to discharge overall design flood out of the reservoir within 10 hours. For this purpose, it is needed to increase the discharge capacity of outlet works.

Next, design an outlet works of variable diameter so that the water depth formed by the flood with the same frequency gets lower and lower. For the outlet works with more than one outlets, in order to keep the discharge rate of the outlet works unchanged, outlet diameters should be increased gradually from bottom to top while keeping the outlets at a given interval. To simplify the design, it is advised to furnish an outlet below the crest level of warping dam, and arrange the outlets with larger diameter above the crest level.

For the outlet works with single outlet, it is advised to arrange two or more discharge orifices of different diameters at the same level to suit the floods of different frequency.

## **2.5 It is essential to operate the outlet works accurately**

In order to prevent ordinary flood from open discharge without desilting, and avoid excessive deposition of fine sediment at the time of great flood, it is needed to operate the outlet works accurately, e. g. opening smaller or fewer outlets for small runoff; and opening larger or several outlets for large runoff.

On the other hand, in order to keep as much coarse sediment as possible in warping dam, it is necessary to observe the sedimentation state before warping dam and outlet works after each flood to ensure the lowest outlet above sedimentation level, that is, dead storage, for the convenience of next retention. The exact height of the lowest outlet above sedimentation level shall be figured out by calculating the total volume of coarse sediment under the condition of design flood. Since the interval between outlets is definite, it's preferred to select upper limit value in actual operation to guarantee that there is sufficient storage capacity to accommodate coarse sediment.

## **2.6 For changing the control area or sediment retention capacity of warping dam**

Based on above ideology, it is advised to increase the control area of key dams and medium dams appropriately, or reduce the sediment retention capacity of warping dam, enhancing the investment benefit and sediment retention benefit of warping dam.

## **3 Effect of “detaining the coarse and discharging the fine” for warping dam**

### **3.1 Coarse sediment retention benefit of warping dam is increased**

As per preliminary estimate, over 90% of coarse sediment can be arrested, and over 70% of fine sediment can be discharged after the design of warping dam is optimized as mentioned above. In this way, more coarse sediment can be detained in limited reservoir capacity. According to the “Warping Dam Construction Program for Water and Soil Conservation of Loess Plateau Region”, 102.8 thousand warping dams will be built in heavy and coarse sediment areas by the year of 2020, providing around 25.0 billion tons sediment retention capacity, which can bring entire heavy and coarse areas under control fundamentally. By applying the method of “Detaining the Coarse and Discharging the Fine”, much more coarse sediment can be retained. It is estimated that gross quantity of coarse sediment detained exceeds 12 billion tons.

### **3.2 Security and stability of warping dam is increased.**

After the sediment retention capacity of warping dam is fundamentally filled, its flood retention capacity will begin to be filled, causing rapid decline of its flood control ability. Applying the method of “Detaining the Coarse and Discharging the Fine” can enhance its flood carrying ability considerably. Thus, its defense capability against flood is increased. Relatively, its flood control capability is increased.

### **3.3 Meaningless consumption of water resources is reduced**

Loess Plateau region is characterized by dry climate and great water surface evaporation. Existing design causes the longer residence time of a flood before warping dam, leading to larger reservoir evaporation and severer infiltration. According to our estimate based on the “Warping Dam Construction Program for Water and Soil Conservation of the Loess Plateau Region”, annual evaporation due to flood detention by warping dams will reach more than 0.9 billion  $m^3$  in the year of 2020, and more than 0.5 billion  $m^3$  water will be needed to compensate groundwater for infiltration loss due to long-time flood detention (not flow into the Yellow River) in 2020. Totally,

river runoff loss will reach 1.5 billion  $\text{m}^3$  in 2020, accounting for 18% of total runoff volume, 8.3 billion  $\text{m}^3$ , available in the control area of warping dams in 2020. “Detaining the Coarse and Discharging the Fine” increases the flood carrying capacity of warping dam to allow the storm flood to pass through in a short time, reducing meaningless water loss due to evaporation and infiltration in the process of long – time residence of flood before warping dam.

#### 4 Design example

Beigou Dam, a key dam, is located in the upper reach of Chenjiagou Gully, 40 km southeast of Yulin City, Shaanxi Province. The gully is a second – order tributary of Wuding River. The control area of this dam is 6.28  $\text{km}^2$ . Mean annual erosion modulus is 15,000  $\text{t}/(\text{km}^2 \cdot \text{a})$ . Flood calculation result is given in Table 3.

**Table 3 Flood calculation result**

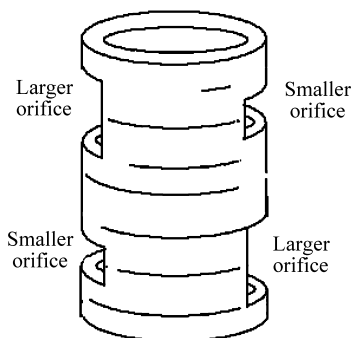
Flood recurrence period (year)	10	20	30	50	100	200	300	500
Flood volume ( $10^4 \text{ m}^3$ )	16.96	21.25	30.90	35.54	43.33	51.43	57.27	66.44

For flood control standard of the warping dam, 30 – year flood was taken as design flood. 300 year flood was taken as check flood. Sedimentation service life, 20 years; Silt retention capacity,  $139.56 \times 10^4 \text{ m}^3$ ; Flood retention capacity,  $57.27 \times 10^4 \text{ m}^3$ ; Total storage capacity,  $196.83 \times 10^4 \text{ m}^3$ ; Dam height, 31.5 m, of which, 25.0 m for silt retention, 3.2 m for flood retention, 2 m for free board, and 1.3 m for settlement. Outlet works is of inclined pipe. Discharge capacity, 0.82  $\text{m}^3/\text{s}$ , was designed to pass 20 – year flood in three days. Three outlets were provided for simultaneous discharge with 0.45 m difference in level and 0.37 m diameter.

As this paper’s recommendation, first of all, calculate the quantity of coarse sediment. Coarse sediment runoff modulus is 7,000  $\text{t}/(\text{km}^2 \cdot \text{a})$  in this area, occupying 47% of soil erosion modulus  $1.5 \times 10^4 \text{ t}/(\text{km}^2 \cdot \text{a})$ . Annual incoming coarse sediment is  $3.26 \times 10^4 \text{ m}^3$ . When the warping dam is operated in the mode, “Detaining the coarse and Discharging the fine”, originally designed silt retention capacity,  $139.56 \times 10^4 \text{ m}^3$ , will be filled up in 43 years, over one time of originally designed service life.

In order to achieve the target, “Detaining the Coarse and Discharging the Fine”, for both ordinary flood and design flood, it is essential to carry out the design of outlet works.

(1) Outlet works shall be of shaft type. Two discharge orifices of different size shall be furnished at the same level to discharge the floods of different frequency (Fig. 2).



**Fig. 2 Schematic Diagram of Shaft – Type Outlet**

(2) Calculate the area of level - 1 outlet provided that a design flood ( $30.9 \times 10^4 \text{ m}^3$ ) shall be discharged in 10 hours; Release rate,  $8.6 \text{ m}^3/\text{s}$ ; Difference in level from outlet center to water surface, 1.5 m. Outlet area shall be calculated using following formula:

$$d = 0.174 = \frac{8.6}{\sqrt{1.5}} = 1.22 \text{ (m}^2\text{)}$$

(3) When the total area of the outlets at each level is  $1.22 \text{ m}^2$ , two orifices of different diameter shall be respectively furnished in the two opposite faces of the shaft at each level to fit the discharge of the floods with different frequency. The two orifices shall respectively have the area of  $0.82 \text{ m}^2$  and  $0.4 \text{ m}^2$ . The  $0.82 \text{ m}^2$  orifice will provide  $5.77 \text{ m}^3/\text{s}$  release rate and the  $0.4 \text{ m}^2$  orifice will provide  $2.82 \text{ m}^3/\text{s}$  release rate.

**Table 4 Flood discharge calculation for different recurrence period**

Outlet Diameter	Release Rate	Flood Volume Discharged in 10h	Discharging Period	Flood with Different Recurrence	Recurrence Period	Discharge Duration
( $\text{m}^2$ )	( $\text{m}^3/\text{s}$ )	( $10^4 \text{ m}^3$ )	(year)	( $10^4 \text{ m}^3$ )	(hour)	(hour)
0.82 + 0.4	8.6	30.96	30	30.90	9.98	
0.82	5.77	20.77	20	21.25	10.23	
0.82	5.77	20.77	10	16.96	8.16	
0.4	2.82	11.88	< 10			

It can be seen from Table 4 that the outlets with above diameter combination can basically meet the requirement for discharging a flood in 10 hours. This diameter combination gives attention to both ordinary flood and design flood for "Detaining the Coarse and Discharging the Fine".

Furthermore, the outlets at each level can be provided with more than two orifices of different diameters so as to carry out "Detaining the Coarse and Discharging the Fine" for different floods in a more accurate way.

(4) Water release culvert and stilling pond shall be designed based on maximum release rate and in accordance with related specification.

It is essential to control the releasing process of each flood. The opening of outlet shall be determined in light of flood volume. The outlet at next level shall be opened promptly when water level has fallen. After each flood, check the sedimentation state before dam, and close the outlets 20 cm above and below sedimentation level for next sediment retention.

## 5 Open questions

(1) It is advised to make a further analysis and study of the various branches of Yellow River, especially, sediment gradation and variation of the branches in heavy and coarse sediment areas.

(2) It is advised to establish a research subject to further study the law of sediment movement in warping dam.

(3) It is advised to optimize the design of warping dam outlet works so that they can fit the discharge of the floods with different recurrence periods in the operation mode, "Detaining the Coarse and Discharging the Fine".

(4) It is advised to make a study of how to establish a warping dam operation & management mechanism for "Detaining the Coarse and Discharging the Fine".

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## Analysis on Retaining and Reducing Coarse Sediment by Check Dam of Typical Catchments in Hekou—Longmen Section

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**Abstract:** In this article, retaining and reducing coarse sediment by the check dams of the five typical catchments: Huangfuchuan Basin, Kuyehe Basin, Wudinghe Basin, Sanchuanhe Basin and Qiushuihe Basin, located in coarse sediment area of Hekou—Longmen Section in the middle reaches of the Yellow River is analyzed profoundly. The amount of coarse sediment retained and reduced by these check dams in different periods are calculated. By analyzing the variation of sediment grain size, check dam area ratio and sediment reduction ratio before and after the check dams and other soil and water conservation measures are put into practices, the author considers that the check dams are the preferred mechanical practice of rapidly reducing coarse sediment that enters the Yellow River. If the average check dam area ratio in the five typical catchments reaches 3.0%, the average sediment reduction ratio can be 60%. Therefore, in order to reduce sediment, especially coarse sediment that enters the Yellow River rapidly and effectively, the area ratio of the check dams in Hekou—Longmen Section should be kept at 3% or so. The two basins of Kuyehe and Huangfuchuan should be preferred as the main catchments that would reduce coarse sediment in the Yellow River.

**Key words:** typical catchments, check dam, coarse sediment, grain size

A check dam is a small mechanical control measure for the sake of soil and water conservation, which is often constructed across a stream to retain soil, to decrease or slow movement of flood, and to promote sediment deposition for farming. The following has been proved by past long term of soil and water conservation practice: a check dam is an important mechanical practice of prevention and fighting against soil erosion of the Loess Plateau; it plays an irreplaceable role in soil and water conservation; it is the preferred mechanical practice of preventing coarse sediment entering the Yellow River, relieving the sedimentation in the downstream river course of the Yellow River and realizing "Against Rising of the Lower Yellow River"; it plays a dominant role for sediment control of sub-basins in the Loess Plateau. Therefore, the study of reducing coarse sediment by check dams is the most important topic among the effect of soil and water conservation measures on reducing sediment in the Loess Plateau all along. However, special emphasis has been laid on total mass of reduced sediment and macroscopic assessment of effect on decreasing sediment in the past research for the middle reaches from Hekou to Longmen (hereinafter referred to as Hekou—Longmen Section), while the study on decreasing the coarse sediment (grain size  $d \geq 0.05$  mm) is insufficient. The disasters caused by the Yellow River should be ascribed to sediment and the coarse sediment is the primary problem. The coarse sediment does the most harm to the Lower Yellow River. It is certain that a check dam has to retain coarse sediment along with sediment trapping. On the basis of the past research, this article analyzes retaining and reducing coarse sediment by the check dams located in the five typical catchments of Hekou—Longmen Section, which aims at support to quickening pace of controlling coarse sediment and the implementation of the policy of "Coarse sediment first, fine sand second" for soil and water losses in the Loess Plateau.

### 1 Analysis on variation of incoming coarse sediment amount and its size in typical catchments

According to the former research of the author, sediment mass reduced by check dams

accounted for 64.7% of the total reduced by the soil and water conservation works in Hekou—Longmen section during 1970 to 1996, where most of the check dams are distributed in the middle reaches of the Yellow River. In the five catchments in Hekou—Longmen section a mass of check dams are distributed, among which Huangfuchuan Basin, Kuyehe Basin and Wudinghe Basin are located in the northwest of Hekou—Longmen Section, Sanchuanhe Basin and Qiushuihe Basin located in the east. The area controlled by hydrologic stations in five typical catchments is 47,460 km<sup>2</sup>, which accounted for 42% area of 113,000 km<sup>2</sup> of Hekou—Longmen Section. The proportion that sediment mass reduced by check dams in Huangfuchuan Basin, Kuyehe Basin, Wudinghe Basin, Sanchuanhe Basin and Qiushuihe Basin accounts for 57.8% , 37.2% , 62.1% , 72.2% , and 64.7% respectively during 1970 to 1996. Except Kuyehe, the check dams on the other four catchments played a leading role in reducing sediment. The soil and water conservation work corresponding to the biggest sediment reduction ratio (the proportion that sediment reduced by check dams accounts for the total sediment reduced by soil and water conservation works) is check dam. The biggest sediment reduction ratio takes place in Sanchuanhe Basin, which exceeds 70% and the smallest in Wudinghe basin, which is close to 40% .

The key point of analyzing the variation of sediment retained and reduced by check dams during different periods is how to calculate the amount of coarse sediment retained and reduced, which is rarely involved in former research. Modified coefficient K, the proportion that coarse sediment takes in the overall sediment can be calculated by the method presented by the author with the data of the component of retained sediment grain size or other data. The modified coefficient K of Huangfuchuan Basin, Kuyehe Basin, Wudinghe Basin, Sanchuanhe Basin, Qiushuihe Basin is 1.68, 1.52, 1.42, 1.22, and 1.35 respectively. The K decreases from north to south and the K of western catchments is larger than that of eastern catchments. There exists a clear regional distributing law for K, which obviously relates to the proportion of coarse sediment in every catchments. Based on the method above, the amount of coarse sediment retained and reduced by these check dams in the five typical catchments during different periods are calculated as well as the proportion of coarse sediment as shown in Table 1.

**Table 1 The result of the amount of coarse sediment retained and reduced by check dams in the five typical catchments in Hekou—Longmen Section**

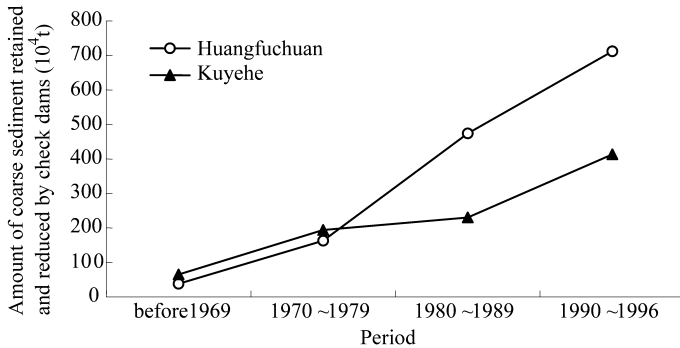
Catchment	Period	Amount of the reduced sediments (10 <sup>4</sup> t)	Amount of the reduced coarse sediment(10 <sup>4</sup> t)	The portion of the coarse sediment( % )
Huangfuchuan	1954 ~ 1969	47	38	49.9
	1970 ~ 1979	189	163	51.2
	1980 ~ 1989	580	474	48.6
	1990 ~ 1996	970	712	43.7
Kuyehe	1956 ~ 1969	104	65	41.2
	1970 ~ 1979	299	194	42.8
	1980 ~ 1989	301	230	50.0
	1990 ~ 1996	602	413	45.1
Wudinghe	1956 ~ 1969	1,130	532	33.2
	1970 ~ 1979	4,810	2,485	36.4
	1980 ~ 1989	2,750	1,227	31.4
	1990 ~ 1996	1,280	468	25.8

Continued to Table 1

Catchment	Period	Amount of the reduced sediments ( $10^4$ t)	Amount of the reduced coarse sediment ( $10^4$ t)	The portion of the coarse sediment (%)
Sanchuanhe	1959 ~ 1969	117	27	18.5
	1970 ~ 1979	641	155	19.8
	1980 ~ 1989	896	190	17.4
	1990 ~ 1996	827	121	12.0
Qiushuihe	1959 ~ 1969	134.5	43	23.9
	1970 ~ 1979	565.5	174	22.8
	1980 ~ 1989	339	94.5	20.6
	1990 ~ 1996	661.5	141	15.8

The following can be seen from Table 1:

(1) The amount of coarse sediment retained and reduced by the check dams in Huangfuchuan Basin and Kuyehe Basin tends to increase through years. But they are different in specific variation process. The amount of coarse sediment retained and reduced by these check dams on Kuyehe Basin was larger than that of Huangfuchuan Basin before 1980 while that of Huangfuchuan Basin is apparently larger than that of Kuyehe Basin and increases more quickly after 1980 than before 1980. The value of the intersection point of two lines is about 2,000,000 t per year (Fig. 1). The climbing trend of the two demonstrates that the two catchments' check dams have great potential for retaining and reducing coarse sediment, which is more distinct in Huangfuchuan Basin. It reflects the direction of rehabilitating the coarse sediment source region from one side.

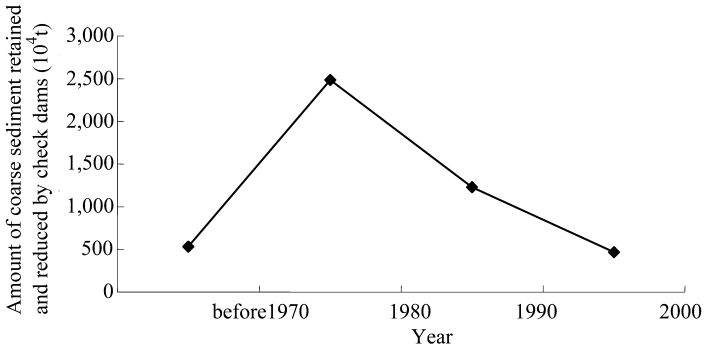


**Fig. 1 The variation process of the amount of coarse sediment in Huangfuchuan Basin and Kuyehe Basin**

(2) The amount of coarse sediment retained and reduced by these check dams in Wudinghe and Sanchuanhe catchments declines through years. In Wudinghe Basin, it came to a head in 1970s and then drops heavily. In Sanchuanhe Basin it came to a head in 1980s and dropped in 1990s. But the variation extent is small. The variation processes are shown in Fig. 2 and Fig. 3.

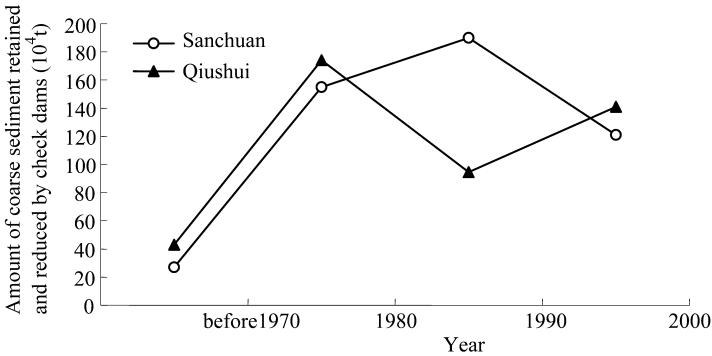
(3) The variation process of the amount of coarse sediment retained and reduced by these check dams on Qiushuihe Basin is different from the others. It increased before 1970s, and went down from 1970s to 1980s, and then rose with a smaller extent than before from 1980s to 1990s. Owing to a sharp decrease of the annual sediment discharge in this basin, the amount of retaining and reducing coarse sediment by check dams was the least in 1980s. The variation process is





**Fig. 2 The variation process of the amount of coarse sediment in Wudinghe**

contrary and is in sharp contrast to that of near basins in 1970s. The variation processes are shown in Fig. 3.



**Fig. 3 The variation process of the amount of coarse sediment in Sanchuan and Qiushui**

(4) The proportion of coarse sediment has fallen due to a decline of annual sediment discharge at Huangfuchuan Basin, Wudinghe Basin, Sanchuanhe Basin and Qiushuihe Basin since 1970s, which shows certain regularity. However, it is different at Kuyehe Basin. The proportion of coarse sediment was 42.8% in 1970s, and reached 50.0% in 1980s and then descended to 45.1% in 1990s. The wave – rise of the proportion of coarse sediment is contrary to the wave – drop of the corresponding annual sediment discharge of each basin, which deserves more attention to be paid.

(5) The proportion of coarse sediment at Kuyehe Basin is the biggest, mainly because of increasing water loss and soil erosion by large scale of mining. Kuyehe Basin is abundant in coal reserve. The large opencast Shenfu Coalfield was developed in 1980s, the area of which is 3,214 km<sup>2</sup>, and the geologic reserve is 33,900,000,000 t. It mainly distributes in the two sides of main and tributary courses of Kuye River from Shenmu to Zhuanlongwan. As many researches have proved, mining can increase the sediment with larger grain size, while soil and water conservation can make grain size of sediment smaller. Mining counteracts the influence on sediment from soil and water conservation such as check dam, etc. Therefore, we still have long journeys ahead of us to fight soil erosion and to prevent coarse sediment from entering the Yellow River.

Furthermore, it can be drawn, from a sharp decrease of the amount of coarse sediment retained and reduced by check dams, that they decreased largely in quantities due to serious silted – up and aging in Wudinghe basin. Dalihe Basin is the biggest catchment and one of the principle coarse sediment sources of Wudinghe Basin. Dalihe Basin's average annual sediment discharge accounts

for 30% of that in Wudinghe basin, and the number of check dams accounts for 25%. According to typical survey on Dalihe basin, the phenomenon of serious siltation on the dams can be found, and the loss of the reservoir storage reaches 45%. Check dams are heavily destroyed by rainstorm and the amount declines sharply in 1990s. The same situation can also be found in Loess Hilly Area from Dingjiagou to Baijiachuan in Wudinghe Basin. Therefore, it is significantly realistic to quicken the pace of soil and water conservation construction with check dams as the emphasis, and to increase retaining and reducing coarse sediment ability of check dams at Wudinghe basin as soon as possible.

## 2 Calculation of the area ratio and the sediment reduction ratio of the check dam in typical catchments

The calculated results of the area ratio (AR) and the sediment reduction ratio (SRR) of the check dams in five large typical catchments of Hekou—Longmen Section are shown in Table 2 and the corresponding histograms are respectively shown in Fig. 4 and Fig. 5. From 1970s, of all the typical catchments, only in Huangfuchuan Basin, the AR and SRR have the synchronous trend to rise. Compared with the 1970s, the AR rises 34.6%, while the SRR rises 48.3% in the 1990s. The increasing trend of SRR shows that the ability of sediment reduction has not got to the maximum. In three typical catchments such as Kuye Basin, Wuding Basin and Sanchuan Basin, AR and SRR of the check dams show the synchronous decreasing trend. Compared with the 1970s, AR in the three typical catchments has decreased by 26.7%, 33.3% and 25.0% respectively, while SRR by 18.9%, 60.9% and 21.0% in 1990s. The relation between AR and SRR of the check dams in Qiushuihe Basin is inordinate and not regular in trend. From the variation of the four phases, the change law in SRR is increase – decrease – increase and the change law in AR is same – increase – decrease. The variation goes to the opposite from the 1970s.

**Table 2 The calculated results of AR and SRR of the check dams in Hekou—Longmen Section**

Period(y)	Ratio(%)	Huangfu	Kuye	Wuding	Sanchuan	Qiushui	Average
before 1969	AR	1.8	1.3	1.8	4.6	4.7	2.84
	SRR	40.7	55.8	76.7	68.8	55.7	59.5
1970 ~ 1979	AR	2.6	1.5	2.4	4.4	4.7	3.12
	SRR	43.3	52.9	84.1	85.1	80.0	69.1
1980 ~ 1989	AR	2.6	1.2	1.9	3.9	5.7	3.06
	SRR	57.2	42.1	62.5	74.9	50.4	57.4
1990 ~ 1996	AR	3.5	1.1	1.6	3.3	4.6	2.82
	SRR	64.2	42.9	32.9	67.2	62.9	54.0
1970 ~ 1996	AR	2.8	1.3	2.0	3.9	5.0	3.02
	SRR	53.9	46.3	62.8	76.7	64.6	60.8

**Note:** AR is defined as the ratio that the saved area of the check dams accounts for the total area saved by the water conservation measure.

Analyzing the relation between AR and SRR of the check dams, SRR can reach 40% and the efficiency of reducing sediment presents prominent if AR of the check dams in Huangfuchuan Basin is more than 2%. In Kuyehe Basin, when AR is more than 1%, SRR can reach more than 40% and the efficiency is obvious, too. In Wudinghe Basin, when AR is more than 1.5%, SRR can reach more than 30%. When AR of check dam in Sanchuanhe Basin is more than 4%, SRR may reach more than 75%. In Qiushuihe Basin, when AR is more than 4.5%, SRR can reach more than 60%. For the same SRR, the AR required is the lowest in Kuyehe Basin, the highest in Qiushuihe Basin, and equivalent in both Huangfuchuan Basin and Wudinghe Basin. From 1970 to 1996, when the average AR of the check dams in 5 typical catchments reaches 3.0%, the average

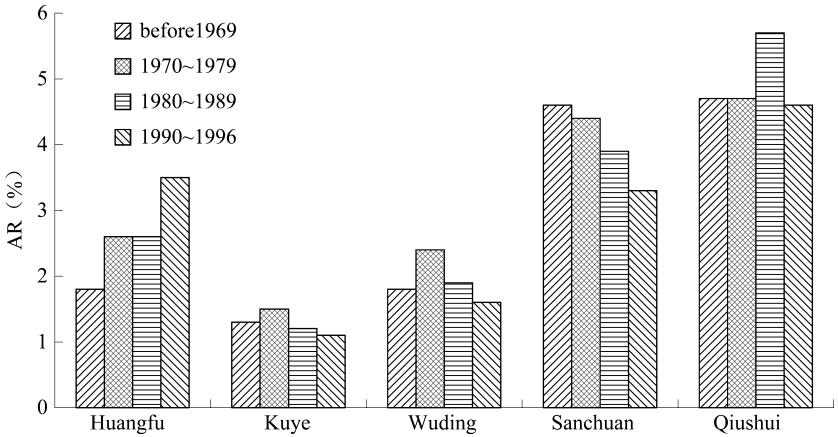


Fig. 4 The AR of the check dam in different period in Hekou—Longmen Section

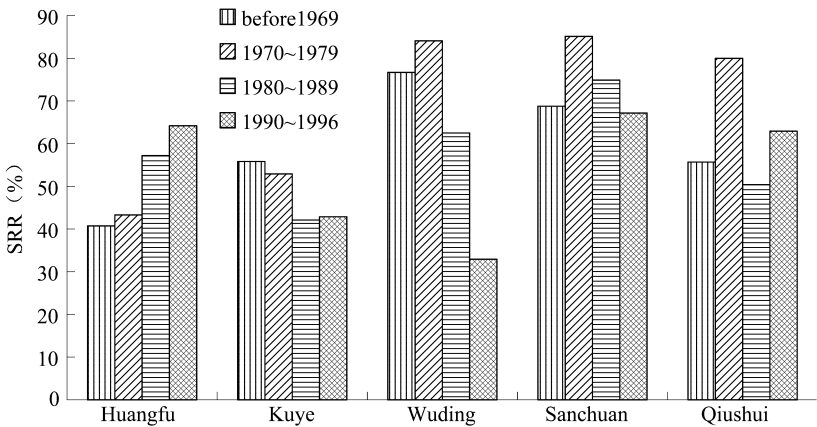


Fig. 5 The SRR of the check dam in different period in Hekou—Longmen Section

SRR can reach 60%. Consequently, the adoption of the check dams is a preferred soil and water conservation mechanical measure to reduce the sediment in 5 typical catchments.

### 3 Grain size variation of typical catchments during a long period

Variation of grain size of the hydrological stations at the estuary of the 5 typical tributaries (Table 3) shows that the median grain size of the sediment has greatly decreased after the soil and water conservation measures were put into practice. Of the 5 catchments, the variation of Huangfuchuan Basin and Kuyehe Basin is more evident than the other three basins. In Hekou—Longmen Section, neither the reduction of the precipitation nor the scouring and siltation of the channel is among the main factors that made the grain size of sediment become more smaller. So soil and water conservation may be the major factor to this consequence. The main measures of the soil and water conservation in Hekou—Longmen Section include making terrace field, planting forest, planting grass, building check dams and so on, and the main hydrologic measures are reservoirs and irrigation areas. Soil and water conservation measures can reduce the water erosion and capacity of transporting sediment through increasing the roughness of the ground surface and slowing down the

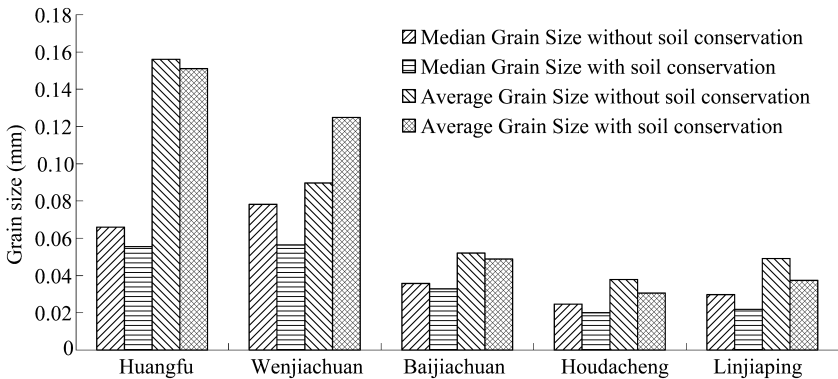
slope in order to reduce sediment. Furthermore, all reservoirs and check dams in catchments mostly have the roles of retaining and reducing coarse sediment and discharging fine sediment. The consequence of all the measures is to diminish the grain size of the sediment that enters rivers. The histogram which reflects the variation of grain size before and after the implementation of these measures has shown in Fig. 6. We can conclude from this figure that both the median grain size and the average grain size of sediment have become smaller after the comprehensive soil and water conservation measure was put into practice in all catchments except Kuyehe Basin. Due to the human activities such as mining, the average grain size of sediment has become larger though soil and water conservation works were put into practice upstream to Wenjiachuan hydrological station in Kuyehe.

**Table 3 The variation of the grain size of sediment before and after the soil and water conservation measures were put into practice**

Stream	Hydrological station	$d_{50}$ (mm)	$d_{50}$ (mm)	$d_{cp}$ (mm)	$d_{cp}$ (mm)
		Without soil conservation	With soil conservation	Without soil conservation	With soil conservation
Huangfu	Huangfu	0.066,0	0.055,6	0.156,0	0.151,1
Kuye	Wenjiachuan	0.078,3	0.056,4	0.089,7	0.124,9
Wuding	Baijiachuan	0.035,8	0.032,9	0.052,0	0.048,8
Sanchuan	Houdacheng	0.024,7	0.020,0	0.037,8	0.030,6
Qiushui	Linjiaping	0.029,8	0.021,9	0.049,2	0.037,4

**Notes:** (1) The data series of the last year is 1996. Some hydrological stations are lack of the data in 1994. Part of data above is from the reference.

(2)  $d_{50}$  represents the median grain size and  $d_{cp}$  stands for the average grain size.



**Fig. 6 Histogram of the variation of the sediment's grain size before and after the soil conservation is brought into effect**

#### 4 Differences of typical catchments between the east and the west in Hekou—Longmen Section

(1) As analyzed above, in the typical catchments like Huangfuchuan, Kuyehe and Wudinghe which are located in the northwest of the Hekou—Longmen Section, the modified coefficient K of the coarse sediment is larger than that of the eastern typical catchments such as Sanchuanhe Basin and Qiushuihe Basin. The larger the portion of the coarse sediment takes, the larger the value of K will be.

(2) AR and SRR of the check dams in eastern typical catchments are much larger than those

of the northwest, which shows that the potential to construct check dams in the western part is much bigger, though being in the same loess hill and ravine area. It is necessary to accelerate construction of the soil and water conservation project, among which check dams play a dominant role.

(3) The median grain size and the average grain size of the sediment in the three northwestern typical catchments are much larger than those of the other two typical catchments in the east. And the two indexes mentioned above decrease from north to south in each basin.

(4) The amount of coarse sediment reduced by every hectare area of the check dams in five typical catchments in the Hekou—Longmen Section from 1970 to 1996 are shown in Table 4.

**Table 4 The average ration of coarse sediment retained and reduced by check dams in typical catchments in the Hekou—Longmen Section from 1970 to 1996**

Basin	Saved area in silted area by check dam (hm <sup>2</sup> )	Amount of the coarse sediment reduced by check dam (10 <sup>4</sup> t)	The ration of the coarse sediment reduced by check dam (t/(hm <sup>2</sup> · a))
Huangfu	911	420.5	4,620
Kuye	950	264	2,780
Wuding	11,190	1,500	1,340
Sanchuan	2,075	159	767
Qiushui	1,420	136	958

From this, the value of the sediment retained and reduced by the check dams is ordinal decreased from north to south; the fixed amount (the coarse sediment retained and reduced within efficient elemental area) of the sediment retained and reduced by the check dam in the northwestern typical catchments is larger than that of the east in order of magnitude, which shows the role of the check dams in retaining and reducing sediment in the area where coarse sediment concentrated intensively are even larger and wider than that of other areas. Therefore, in order to utilize the coarsest sediment, to reduce the coarse sediment in the Yellow River and to control the water and soil losses, it is wise to view Kuyehe and Huangfuchuan as the preferred focal catchments.

## 5 Conclusions

(1) After implementing the comprehensive soil and water conservation measures, the median grain size of the sediment in the five typical catchments obviously becomes smaller, as well as the average grain size except in the Kuyehe.

(2) A check dam is the preferred mechanical measure for quickly reducing the sediment entering the Yellow River in Hekou—Longmen Section. If the average AR of the check dams in the five typical catchments reaches 3.0%, the average SRR of the check dams can be 60%.

(3) In order to reduce the sediment, especially the coarse sediment entering the Yellow River efficiently and quickly, the AR of the check dams in the typical catchments in Hekou—Longmen Section should be kept at the value of 3.0%.

(4) The preferred catchments should be the Kuyehe Basin and Huangfuchuan Basin, considering the reduction of the coarse sediment entering the Yellow River.

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## Thesen Islands: Innovative Environmental Advancements Marina Development

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**Abstract:** Thesen Islands development is an ambitious and technically complicated project where the 96 – hectare Thesen Island in Knysna, South Africa, is master planned into an estate of 19 islands surrounded by wide tidal waterways linked by bridges. Fifteen kilometres of pristine water front property needs to be protected in the most environmentally friendly way possible against the erosive forces of fluctuating tide levels and associated wave action to ensure that the islands will be developed in harmony with the Knysna Estuary environment.

After thorough site trials and investigations, hexagonal woven mesh products; Reno mattresses; gabions and Terramesh? were found to be the only alternative in achieving the onerous standards and criteria as set out in the project specifications, i. e. environmental compliance, durability under aggressive marine environments, ease of installation and vegetation establishment, and cost effectiveness.

The chosen solution is able to protect each idyllic island against scour arising from inter tidal action and can also ensure the stability of the bank especially under rapid draw down conditions.

As a result, the tidal flow around the islands is completely natural with excellent circulation, water quality and minimal silting. A state of the art modelling system developed by The Danish Hydraulic Institute was used to assist with the design and layout of the waterways. Hydraulic and hydrological modelling, which even accounts for climate change, should ensure that the Islands are completely safe from flooding.

A bioengineering approach is being taken to the construction. Indigenous salt marsh plants are being used in conjunction with the inert materials in the inter – tidal zone. Small fish and marine life find food and shelter in the plants and natural rock along the edges of the waterways, which in turn, attract a diversity of birds and larger fish resulting in habitat improvement. The rock filled gabions provide surfaces for growth of algal – microbial films, which may contribute to nitrogen and phosphorus uptake from the tidal flow, thus reducing phytoplankton growth potential in the canals.

The Deputy Minister of Environmental Affairs and Tourism, Minister Ms. R. T. Mabudahfhasi has commended the developers “for the most responsible manner in which they conducted, supported and financed the environmental research, which probably represents the most comprehensive, professional and detailed Environmental Impact Assessment ever undertaken in South Africa”.

**Key words:** dewatering, salt marsh transplantation, environmental compliance, marina development, gabion technology, bioengineering

Seven years of detailed Environmental Impact Assessments, the evaluation of 26 development scenarios and hundreds of individual detail studies led to the final authorisation and permit approval by Environmental authorities and the South African government for the redevelopment of the 96 hectare Thesen Island into an estate of 19 islands surrounded by wide tidal waterways linked by bridges. The 101 separate conditions of approval imposed on the developers, are constantly monitored by a Government appointed Monitoring Committee as the project unfolds.

The result: world leadership in innovative design and construction with the primary focus on

enhancing the sensitive environment of a coastal estuary.

From the beginning of time man has had a fascination to live at the water's edge. Unfortunately for man, the interface between land and water is subject to the laws of dynamic equilibrium; continuously adapting in accordance to the natural elements: rain, winds, currents, erosion and their interaction. Population growth and the ever – rising cost of land have lead to waterside developments, which maximise the area of land available to be developed, often to the detriment of the environment.

This paper highlights innovative advancements in the design and construction of waterfront developments in areas of high environmental sensitivity and natural beauty. A case study for Thesen Island, an island located in the Knysna Estuary on the east coast of South Africa is presented. The paper outlines how adverse physical conditions, historical pollution problems, extremely rigorous environmental legislation and challenging design problems are being overcome to allow this development to take place not only in an environmentally excellent manner but also to extremely high aesthetic quality standards (Fig. 1, Fig. 2).



**Fig. 1 World Map**



**Fig. 2 Sa Map**

## 1 Project background

More than one hundred years ago Thesen Island was developed as an industrial operation. The absence of a railway line in the region necessitated the use of the island as a harbour and port for loading and unloading of ships – mostly ferrying indigenous hardwoods from the fantastic forests in the region to foreign ports. The timber industry developed, and for the past 70 years a wood treatment facility (Creosote and CCA plant) operated on the island. The environmental impact of this operation on the estuary is detrimental in two ways:

(1) Chemicals used in the treatment of timber have contaminated a part of the island.

(2) A solid causeway used as an access road from the mainland to the island prevents the circulation of water and subsequent flushing out of impurities in the estuary.

The island is unique in the South African context as it is the only one of possibly four habitable islands in the country. Also it was totally inaccessible to the local population because of the industrial activities on the island, yet it is situated in the middle of a town that won the award as the best tourist town in South Africa.

In the early 1990's planning for the rehabilitation of the island with the aim of redevelopment of the island into a waterfront/marina and housing development began.

Seven years of detailed Environmental Impact Assessments, the evaluation of 26 development scenarios and hundreds of individual detail studies led to the final authorisation and permit approval by the Environmental authorities and the South African government for the redevelopment of the island. One hundred and one separate conditions of approval are imposed on the developers, and these conditions are constantly monitored by a Government appointed Monitoring Committee as the project unfolds.



Development construction started in August 2000 and now, almost 12 years since investigations began, Phase Three out of five development phases is taking place. Thesen Islands is now classified not only as the largest marina development in South Africa, but also the first to take place on an island in South Africa. The construction of the first houses (48) is underway and a major component of the civil construction work is completed. To date there have been basically no serious construction problems encountered and the project is on schedule and within the set budgets. This can only be contributed to the serious adherence to the conditions of approval, the strict monitoring and absolute sensitive way each subsection of the development is approached and built.

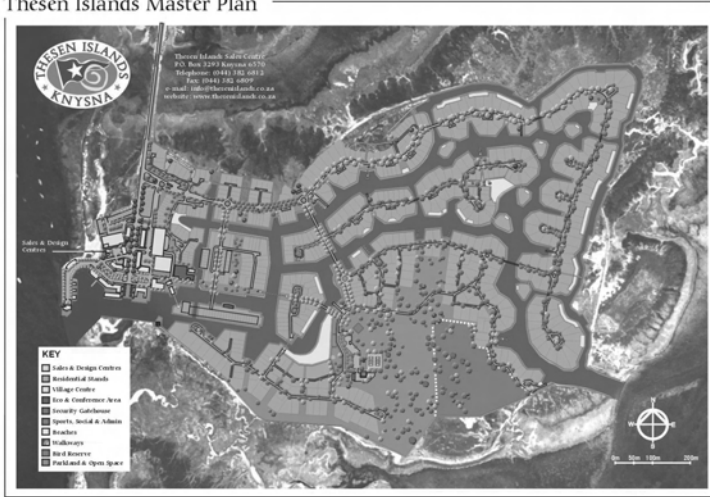
The process of getting to the current project status has not been a simple one. Much time was taken by research and on developing plans to protect and even improve the environment in one of South Africa's most scenic regions.

The South African Deputy Minister of Environmental Affairs and Tourism, Minister Ms. R. T. Mabudahfhasi has commended the developers, as well as the principal designers, Chris Mulder and Associates Inc, "for the most responsible manner in which they conducted, supported and financed the environmental research, "which probably represents the most comprehensive, professional and detailed Environmental Impact Assessment ever undertaken in South Africa"

## 2 Objective of the marina development

Thesen Islands development is an ambitious and technically complicated project where the 96 – hectare Thesen Island has been master planned into an estate of 19 islands surrounded by wide tidal waterways linked by bridges (Fig. 3).

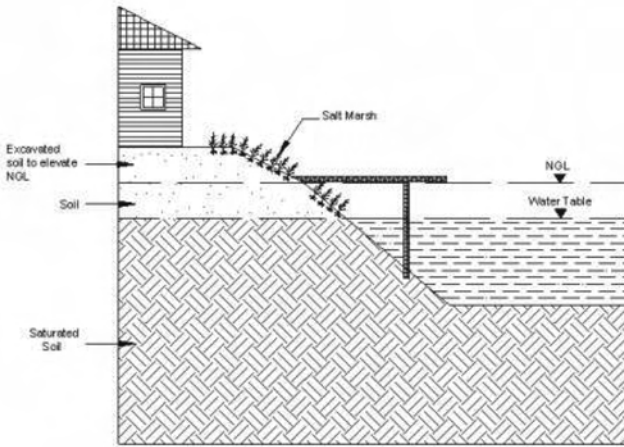
Thesen Islands Master Plan



**Fig. 3 Thesen islands development plan**

The intention is to construct a marine development as presented in Fig. 4 under extreme adverse conditions.

Protecting 15 km of pristine water front property in the most environmentally sensitive way possible against the erosive forces of fluctuating tide levels and associated wave action to ensure that the islands will be developed in harmony with the Knysna Estuary environment is not a simple task, as this paper outlines.



**Fig. 4 Schematic representation of proposed cross section**

### 3 Obstacles to the marina development

Physical constraints and environmental restrictions, unique and extreme in this project, influence the possibility of the site being developed at all. A summary of the constraints is presented in Table 1.

**Table 1 Obstacles to the marina development**

Constraint	Description
Soil properties	The soil profile, to a depth of 2 m, is composed of estuarine fine sands. In areas where the ground has not been consolidated (e. g. at the water's edge) the soils are very soft and compressible. The fine sands occurring on the island have a friction angle of 130 and are susceptible to liquefaction. This implies that under conditions of even moderate vibration they exhibit very low bearing capacity. When saturated they flow and are virtually impossible to compact using vibratory equipment
Water levels	The natural ground level of the island is on average 2.0 mamsl (meters above mean sea level). High and low water levels vary between 1 meter above and 1 meter below mean sea level respectively. The mean water table level is at about 0.6 mamsl
Ground levels	The ground level on the islands is designed to be raised during development to between 2.8 and 3.0 mamsl. The Council for Scientific and Industrial Research (CSIR), South Africa calculated the safe ground floor level of buildings. This was based on the highest astronomical spring tide with the extreme effect of river floods, bad sea conditions, atmospheric pressure and strong winds all combined together at one time, plus the allowance for global warming and an extra safety factor added

Continued to Table 1

Constraint	Description
Geometric	<p>These constraints pertain to the dimensions of the canals;</p> <p>Canal width: As a result of the hydraulic modelling and to maximise available land area, the maximum allowable width of the canals is 30m.</p> <p>High tide: Canal banks to be protected from high water levels and wave action impacting on, or causing damage to, infrastructure</p> <p>Low tide: Canals needed to remain navigable at low tide, with provision for boats to moor to individual jetties</p>
Environmental; Conditions of approval	<p>In order to approve the change in land use and allow a marina – type development, regulatory authorities specified 101 conditions of approval. The most stringent pertains to maintaining the extremely high ecological value of the</p> <p>estuary. For the first time in South Africa and potentially in the world, all salt marsh areas disturbed by the development have to be rehabilitated in such a manner so as to ensure “NO NETT LOSS OF SALT MARSH”. Furthermore an Intertidal Reserve needs to be designated along all canal edges to protect the water edges from the erosive forces of fluctuating tide levels and associated wave action to ensure that the islands are developed in harmony with the Knysna Estuary environment</p>

## 4 Marina development

### 4.1 Technical design

#### 4.1.1 Canal design and layout of the waterways

The canal design and layout of the waterways was undertaken by the CSIR. Hydraulic and hydrological modelling was used to assist in the design and layout of the waterways. The evaluation of the circulation and current velocities in the canal development was based on computer model simulations using the “Knysna Estuary Model”, previously set up at the CSIR with the Mike 11 1D modelling system.

Mike 11 is a user – friendly and state – of – the – art modelling system which has been developed over the past 20 years by the Danish Hydraulic Institute and has been applied worldwide. It is a modelling system for one – dimensional flow in rivers and estuaries. The model is used primarily to determine water levels, flows and velocities. It can also be used for transport dispersion, water quality or sediment transport.

The canal design was modified until the model simulation showed that the final canal lay out would allow for excellent water circulation, whilst having low enough water velocities (below 0.5 m/s) to prevent scour of the canal banks.

The importance of good circulation is two – fold;

(1) Fauna and flora along the canal bank will flourish with a fresh supply of nutrients and aerated water. Good circulation will also regulate the water temperature, thereby having a positive impact on the development of a healthy ecosystem.

(2) Should there be an accidental spillage or pollution problem, the excellent circulation will assist in efficient remediation of the water quality.

#### 4.1.2 Evaluation of alternatives for embankment stabilisation

Shoreline structures have to withstand a combination of actions induced by waves, currents and

differences in water levels. The chosen structure must be able to:

- Remain stable when subject to deformations due to settlement and scour;
- Protect the shoreline in the entire zone of inundation; and
- Withstand cycles of continuous saturation and draw down.

Consulting Engineers, Arcus Gibb (Pty) Ltd considered various bank protection options, including timber, rip rap, pre – cast concrete elements, Reno mattress and gabion / Reno mattress combinations. A cost analysis and feasibility study was conducted and the results discussed with the regulatory authorities.

Evaluation of the alternatives at desktop level was followed by a series of field trials.

Principals for the desktop study evaluation included:

(1) Practical feasibility: from an analytical point, would engineered design of the structure be possible?

(2) Sensible construction techniques: to allow for simple transformation from engineering designs to practical implementation during construction.

(3) Aesthetics: the principal designers and master planners, the developer, regulatory authorities and interested and affected parties (IAP's) insisted that the chosen solution be aesthetically pleasing.

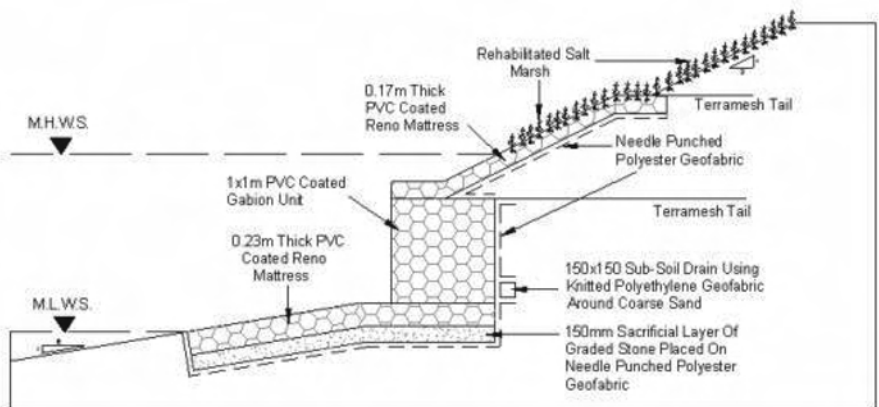
Field trials of the alternatives were then carried out above ground. These addressed practical issues of construction, which had a fundamental impact on ensuring that the structures built correspond to those on which the design calculations had been based.

Gabion and Reno mattress combinations were selected as the most appropriate solution because of their flexibility to meet with the geometrical constraints of the canal embankments, durability under harsh marine environments and ability to lend themselves favourably to environmental rehabilitation.

#### 4.1.3 Structural design

Structural designs were completed by the consulting engineers using hand calculations and confirmed with computer – generated models. These results were reviewed by an independent geotechnical engineer and further confirmed by African Gabions (Pty) Ltd using Maccaferri design software. The profile was tested against slip circle failure, assuming the material behind the gabions to be fully saturated.

A schematic of a typical cross section, "Type B", is shown in Fig. 5.



**Fig. 5 Type B cross section**

The basic design consists of an underlying geotextile filter combined with a granular filter, overlain by 230 mm deep Reno mattress, a 1 mm x 1 mm gabion with a Terramesh<sup>®</sup> tail used as a

lid and a 170 mm deep Reno mattress lined with a geofabric basket. The signatory double twisted mesh of the gabions, Reno mattresses and Terramesh<sup>®</sup> tail is galvanised and PVC coated.

Site – specific variations of this design, for example additional gabions placed on top of the 1 × 1 gabion, are being used to create various finishes, resulting in numerous other cross – section types. In all cases the components of “Type B” are common and fundamental to the basic design.

## 4.2 Construction: dewatering

Ordinarily construction in the existing environment would be impossible due to liquefaction of the soils. Construction is only made possible through dewatering, which improves the soil characteristics enabling excavation of the canals.

Dewatering wells, installed to a depth of six meters below surface, are operated 24 hours a day, pumping water out at a rate of 20 L per second into cofferdams for settlement prior to being pumped into the estuary three days later. The dewatering keeps the water level to about 200 mm below the canal bottom, or dry to a depth of about 1.2 m below sea level. Dewatering needs to be maintained until the Reno mattresses and gabions have been placed and backfilled. The dewatering process is captured in Fig. 6.



Fig. 6 Dewatering

## 4.3 Unique advancements in double twist technology

The use of gabion and Reno mattresses has been proven historically and as such, is well documented. It is not this paper’s intention to repeat the information, but rather to highlight specific characteristics related to the design and construction of gabions and Reno mattresses that are unique to this project and therefore contribute to advancements in gabion technology.

### 4.3.1 “Topless” gabions

The Terramesh<sup>®</sup> system researched and developed by Officine Maccaferri Spa, comprises a front face and reinforcement tail made from one continuous panel. At Thesen Islands the lid of the traditional 1 mm × 1 mm gabion is replaced with a Terramesh<sup>®</sup> tail serving the dual purpose of

closing the gabion and forming a reinforcement layer in the backfill.

#### 4.3.2 Vertical tensioning and formwork

Gabions are traditionally manufactured with the double twist mesh in a horizontal orientation. At Thesen Islands all gabions are custom made with the mesh in a vertical orientation along the front face. This, together with the use of a steel frame supporting the gabion during the rock packing process, contributes to the impeccable finish achieved with the gabion construction.

#### 4.3.3 Horizontal tensioning

Aesthetics is further enhanced through the use of longitudinal tensioning. This process involves assembling a row of gabions, packing the first compartment, tensioning wire to a fixed point on this end, packing the last compartment on the other end of the row and using a fencing wire tensioner to tension the wire through the gabions until it is taught.

#### 4.3.4 Innovative bracing techniques

Bracing is the process of tensioning the front and back of the gabion to prevent bulging of the front face. It is a technique used to contribute to the aesthetic appearance of a gabion. Traditionally binding wire is threaded through the front and rear faces and twisted in to middle to tension it. This can be a time consuming task, hence at Thesen Islands, pre – formed heavy gauge braces are specified to ensure time and hence cost effective construction.

#### 4.3.5 Unique rock specification

SABS1200DK specifies a limitation on the minimum effective diameter and maximum dimension of rock for gabion and Reno mattress construction. In doing so the SABS Specification excludes rock that has a small minimum diameter but a large maximum dimension. This of course leads to a large percentage of rock being rejected on site. In this project, the larger dimension is accounted for and rock that has a minimum diameter smaller than the mesh diameter but a maximum dimension greater than 150 mm but up to 300 mm, is deemed acceptable. In this way, a larger proportion of the rock delivered is used with less wastage on site.

#### 4.3.6 Combined mechanical and labour intensive construction

The lower, 230 mm Reno mattress is pre – filled prior to being placed mechanically into position, where as the gabion and upper 170 mm Reno mattress are hand packed. The combination of mechanical and labour intensive construction allows canal development to take place at a cost – effective rate of about 80 linear meters per day.

### 4.4 Environmental rehabilitation

As outlined in Table 1, “NO NETT LOSS OF SALT MARSH” and creation of an intertidal reserve are part of the Conditions of Approval for the development.

No nett loss of salt marsh implies that existing areas of salt marsh, which will be disturbed by the canals, needs to be transplanted to newly developed areas. In particular along the intertidal reserve, which has subsequently become known as the ecobelt.

The top Reno mattress, shown in Fig. 5 forms the basis for the salt marsh in the ecobelt.

During excavation of the canal the topsoil is removed and stored, while the rest of the excavated material is used to increase the ground level of the newly – created islands as outlined in Table 1. The stockpiled topsoil is used to “fill” the Reno mattress once it is constructed. Thereafter the whole area is planted with indigenous salt marsh and grasses to stabilise the new surface. This is the first time ever in South Africa and probably one of few places in the world where indigenous salt marsh plants are being successfully harvested at this scale and replanted and established at simulated heights and natural conditions.

Transplantation of the salt marsh was initially done using a sod planting (Fig. 7). It is now

being performed using a sod planting method (Fig. 8). The plug planting method was initially used to ensure proper growth through the Reno mattresses lid. Slow growth and the finding of a solution to plant sods directly under the Reno lid, before closure, then lead to the sod planting method. Both methods will in the long term be equally successful but the sod planting method is quicker and cheaper with a faster growth rate.



**Fig. 7 Sod planting**



**Fig. 8 Plug planting**

## **5 Assessment of environmental rehabilitation**

### **5.1 Colonisation of the Marina System by Marine Organisms**

(University of Port Elizabeth findings)

The Thesen Islands Development Committee (TIDC) has commissioned a program to monitor the Thesen Islands marina system for colonisation by Marine Organisms.

To date two samples have been collected and analysed. The first in August 2001, the second in December 2001. The next survey is to be conclude in August 2002.

The program aims to:

(1) Monitor the three main zoological components of the macroscopic biota that might colonise the canals, namely: benthos, zooplankton and nekton.

(2) Possibly identify habitats that might prove suitable for recruitment of sea horses (*Hippocampus capensis*), either naturally or with the aid of artificial habitats.

(3) Assess, where possible, the effects of future boat traffic, by comparing conditions before and after the canals are opened to boats.

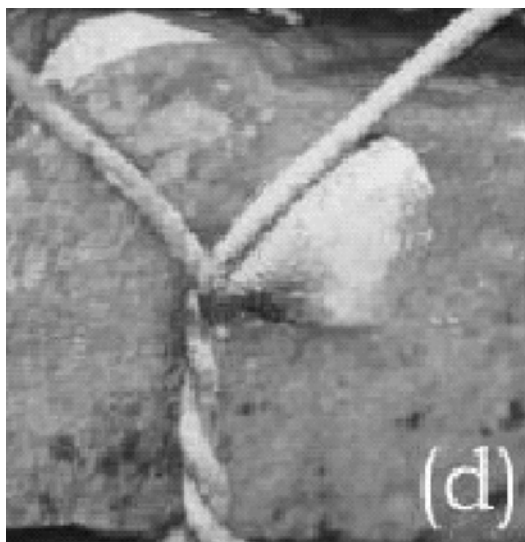
(4) Monitor environmental variables, including sediment type, salinity and temperature at each of the sites.

The aim of the program is to determine the rate and extent of colonisation of the marina canal system by marine organisms and thus determine the extent to which the canal system functions as an extension to the Knysna estuarine ecosystem.

Although the research is in it's initial phase, already "the increase in abundance and diversity among the communities inhabiting the gabions is promising". (Schoeman and Parker - Nance, 2001).

Members of the Benthos community, namely the common mussel (*Mytilus galloprovincialis*) and the egg cases of the common cuttlefish (*Sepia vermiculata*) that were not present in the August sample were present in the December sample. Underwater photographs of the common mussel and cuttlefish egg cases are shown in Fig. 9 and Fig. 10 respectively.

Of particular interest is the gradual increase in diversity at all sites as resident faunas develop. Another consistent pattern is the tendency of both abundance and diversity of epifaunal macrofauna inhabiting the gabions to increase from the high to low water marks. In addition to this clear trend for animals, the gabions at all sites, except one, were coated in a layer of fine green algae, suggesting an increased productivity on the gabions.



**Fig.9 Common mussel**

The presence of the common hermit crab *Diogenes brevirostris* at two sites further indicates improving environmental conditions in the shallow water.

In general, the site closest to the marina mouth, subjected to the most flushing through tidal activity, has the most abundant and diverse fauna, and is also most similar to the estuarine control site.

It is anticipated that with the opening of the canals, subjecting them to greater tidal flushing, that marked changes will take place. The significance of changes in the marine organism colonisation will be assessed over longer time – scales.

## 5.2 Gabions acting as a macro biofilter

The rock filled gabions provide surfaces for growth of algal – microbial films, which may contribute to nitrogen and phosphorus uptake from the tidal flow, thus reducing phytoplankton growth potential in the canals. Considering the depth of the gabion walls, which are permeable to canal water, and the total surface area afforded by the millions of stones packed into the gabions, it is possible that the gabions will act as a macro biofilter. Studies of this property are underway by Dr B R Allanson of the Knysna Basin Project.

## 6 Summary and conclusions

A passion for environmental excellence has contributed to the successful design and ongoing construction of the largest marina development to take place on an island.

Advancements in construction techniques and gabion technology, as well as unique revegetation methods in the form of salt marsh transplantation have made this project possible under extreme physical and environmental constraints.

The appropriateness of gabion and Reno mattress embankment protection is already being exhibited in the numerous research projects that are taking place. Results, despite the project being in its preliminary phases, are already showing successful environmental rehabilitation.

Watch this space!



**Fig.10 Cuttlefish egg cases**



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# Ice Flood Control of Lower Yellow River after Operation of Xiaolangdi Reservoir

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**Abstract:** The Yellow River ice flood is a severe natural disaster taking place in the lower reaches of Yellow River. Since it is a difficult problem to be resolved, there was an old parlance in history “If the burst of the Yellow River is caused by ice flood, the river channel officials would not be punished”. Since the Xiaolangdi Reservoir was put into operation, the flow of the lower reaches has been effectively controlled and the problem of ice flood of the Shandong section basically resolved. However, new problems appear because of river frozen due to small flow discharge, trans – basin water diversion and occurring of unexpected events. Efficient measures are demanded to be taken to solve such new problems to ensure safety against ice flood.

**Key words:** ice flood control, the Lower Yellow River, Xiaolangdi Reservoir

## 1 Review of ice flood control of Lower Yellow River

### 1.1 Ice disasters

The ice disaster of the Yellow River is a severe natural disaster to the lower Yellow River. It has been well known for frequent dike breach and difficult to prevent, and regarded as an unconquerable natural disaster. There was an old parlance “If the Yellow River burst its banks caused by ice flood, the river officials would not be punished” in history. According to the historical catastrophic data for the 54 years from 1883 to 1936, there were more than 40 ice floods that caused bursts in 21 years, two bursts every five years in average. After the foundation of PRC, the ice flood regime of the lower Yellow River was still grim. The Yellow River channel froze up for 51 years and serious ice run flood occurred in eight years during the 58 years from 1950 to 2007. The freeze – up river channel was 703 km long in 1969, with the upper limit to Huayuankou, Zhengzhou city. In some serious ice jam flood years, bankfull discharge took place in some sections, and such dangerous situation as embankment collapses, water piping, penetration and even bursts could be witnessed. Two bursts occurred successively in Wangzhuang and Wuzhuang of Lijin county, Shandong Province in 1951 and 1955, that caused a heavy loss. Because of the two bursts caused by ice flood, we can merely say that we have achieved great success for 60 years without burst in summer and autumn flood seasons.

### 1.2 Causes of ice flood

The lower Yellow River channel is classified as unstable frozen river. The disasters caused by an ice flood rely on many factors such as location, air temperature, water flow and river channel conditions.

As geographical location is concerned, the lower Yellow River channel runs at north – east, south – west directions, the upper line lies at north latitude  $34^{\circ}50'$ , while the sea entrance is at north latitude  $38^{\circ}00'$ , with latitude difference of  $3^{\circ}10'$  between the both ends.

Water flow in the lower Yellow River in freeze – up period is small, the ice cover is low, which blocks the water flow passing through. In the freeze – up period, the water storage below the ice releases and increases gradually, which easily forms “violent breakup of ice”.

As river channel condition is concerned, the upside of the lower Yellow River channel is wide, shallow and scattered and the downside is bending and very narrow. Ice jam easily appears in both freeze – up and break – up periods, which forms ice damming and causes ice flood.

## **2 Function of Xiaolangdi Reservoir in lower Yellow River ice flood control**

### **2.1 Brief introduction of Xiaolangdi Reservoir**

Xiaolangdi Reservoir, as a large scale reservoir, located at the end of the Yellow River's trunk stream, was put into effects for food control in 2001. It's major objectives are flood control (including ice – flood) and reducing the sedimentation, as well as water supply and power generation. The Xiaolangdi Reservoir has a total storage capacity of 12.65 billion  $m^3$ , including 7.55 billion  $m^3$  for sand trapping, 4.05 billion  $m^3$  for flood control and 1.05 billion  $m^3$  for sediment diversion, which can promote the flood prevention standard of the lower Yellow River from a 60 – year occurrence to a 1,000 – year occurrence.

### **2.2 The operation of Xiaolangdi reservoir essentially resolves the ice – flood issue of the lower Yellow River**

The Xiaolangdi Reservoir, after being built based on design, is facilitated with an ice flood control capacity of 2 billion  $m^3$ , adding 1.5 billion  $m^3$  ice flood capacity of Sanmenxia Reservoir (water level:325 m), its total capacity reaches 3.5 billions  $m^3$ . The operation of the Xiaolangdi Reservoir can deal with common situation of the lower Yellow River for ice flood control. But if the ice flood situation is severe, together with the Sanmenxia Reservoir, it can restrict the ice flood peak flow of the lower Yellow River below 1,000  $m^3/s$ , basically releasing threatening of ice flood to the lower Yellow River.

### **2.3 Flood discharge capacity increase obviously after water and sand regulations of Xiaolangdi reservoir**

After implementation of the Xiaolangdi Reservoir, the water and sediment regulation had been done successively in five years from 2002 to 2006. The water level of the downstream river section, with river flow reaching 3,000  $m^3/s$ , decreased 1.07m and even 1.48m at the most. The lowest river channel bankfull discharge increased from 1,800  $m^3/s$  before water and sediment regulation to more than 3,400  $m^3/s$ . During the and sediment regulation period of 2006, the peak river flows in Gaocun station and Lijin station, Shandong section reached 3,900  $m^3/s$  and 3,750  $m^3/s$ , respectively. No overflowing occurred in the floodplain and flood carrying capacity of the river channels increased obviously.

## **3 Changes of lower Yellow River ice flood regime after the operation of Xiaolangdi Reservoir**

Since the Xiaolangdi Reservoir was put into operation, the water flow entering the lower Yellow River channel in ice flood period has decreased to a large extent. The lower channel freezes up annually while the freeze – up period is getting short apparently.

### **3.1 Water flow decreases in large scale, freeze – up probability increases**

After the operation of the Xiaolangdi Reservoir, during the period from 2001 to 2007, the water entering Gaocun station, Shandong section reduced apparently except increasing by 20% from 2003 to 2004. Particularly, in 2001 ~ 2002 and 2002 ~ 2003, it was cut down by 55% ~ 71%. With the less flow concentration and water consumption in winter by the region along the Yellow River, the

Yellow River flow in Shandong section reduces gradually and reduces more in Hekou section. In the melting ice flood 2002 ~ 2003, the average flow touched down to  $36 \text{ m}^3/\text{s}$ , 93% less than a typical year. The decrease of river flow increases the possibility of river channel to freeze up.

### **3.2 The temperature of water discharging from the reservoir increases while the frozen up line decreases**

According to calculation, when water released from the reservoir is  $4 \text{ }^\circ\text{C}$ , and freeze - up flow is controlled at  $500 \text{ m}^3/\text{s}$  or so, the river channel upstream of Gaocun, even in very cold year, won't freeze up. The initial freezing up location moves about 200 km downwards. If the temperature of water out of the reservoir raises  $1 \text{ }^\circ\text{C}$ , the initial freezing up position will move 50 km downwards. After the operation of Xiaolangdi Reservoir, the discharged water temperature is about  $8 \sim 9 \text{ }^\circ\text{C}$ , which efficiently eases lower river ice flood regime. In the year 2002 ~ 2003, 95 frozen sections of the lower river reached 330.6 km, which is the longest from 1981. The uppermost frozen section was in Mudan district, Heze city, Shandong.

### **3.3 The air temperature being higher generally**

During the ice flood season from 2001 to 2007, the air temperature of the lower Yellow River has not been low generally. The average air temperature in ice flood period is higher than the average except the year 2004 ~ 2005. Thereinto, the average air temperature in 2006 ~ 2007 is  $1.8 \text{ }^\circ\text{C}$  higher than the average of the previous years. The average air temperature of ice flood periods from 2001 to 2007 is  $0.87 \text{ }^\circ\text{C}$  higher than the previous average.

### **3.4 The frozen length shorten greatly, the river channel is easily to freeze and break**

The average frozen length of the ice flood periods from 2001 ~ 2007 is 129 km, which is merely 51% of 254 km, the average freeze - up length from 1950 to 2000, which was caused by many factors such as flow, air temperature, water temperature and river channel. Water flow of the lower river increases 20% and the air temperature is close to the average of the previous years, the year 2003 serious autumn flood brush the river channel in large extent, the froze section is merely 1.5 km, which lasted one day. In the year 2002 to 2003 the flow of runoff decreased 71%, 95 frozen sections extends 330 km long, which is the longest frozen length after the Xiaolangdi Reservoir was operated. In the year 2005 to 2006 the flow of runoff of the lower river reduced 24%. Because the air temperature changed greatly, an infrequent phenomena named "three freeze - ups and three break - ups" occurred. The longest frozen up reach consists of 15 sections with 57.4 km in length.

## **4 Negative effects of the lower Yellow River ice flood control**

### **4.1 A new trouble brought about by interbasin water transfer to anti - ice jam flood regulation**

During ice jam flood period from 2001 to 2007, Weishan Sluice Gate had provided water to Tianjin city and Hebei Province four times. When it encounters bad weather, the supply will stop at any moment. Moreover, it increases the river flow downwards the Yellow River, which may cause "violent break - up of ice". Even if the Xiaolandi shut off immediately when ice jam flood is occurring in Shandong section, only the channel storage water can cause ice jam flood. In Dec 2002, the Yellow River diversion from Jinan to Tianjin was blocked by ice jam that broke up the channels, however, timely plugging was implemented there, otherwise, the diversion might be cut off. If the diversion were cut off, the flow would reach more than  $100 \text{ m}^3/\text{s}$ , which is more than thrice of freeze up flow. Because it was in freeze - up period then, some section probably appeared ice jam.

## 4.2 Floating bridges across river influence ice flood safety

There are 48 floating bridges over Shandong section, which play important roles in intercoastal traffic and economic development along the river. But it directly threatens the safety of anti ice jam flood as well. In the ice flood season, the floating bridges hold back ice and water. If not removed in time, it might cause freeze up and even partly ice jam, destroying floating. At the same time, ice flood endangers the safety of people and vehicles crossing the floating bridges.

## 4.3 Pay full attention to the emergent incidents affecting anti ice jam flood

In the second freeze up period in ice jam flood season of 2005 ~ 2006, water pollution incident occurred in Yi River. The Xiaolangdi Reservoir increased its water flow. When the large flow entered Binzhou section, flow in Lijin station reached  $511 \text{ m}^3/\text{s}$ , 1.8 times as much as freeze-up flow of  $280 \text{ m}^3/\text{s}$ . At that time, Binzhou was in freeze up period, the water level mostly got jumped, which swelled and broke the ice. Then water flowed down with ice, which caused ice jam locally, which increased upriver water level. The water level of Binzhou increased 2.83 m and 0.11 m higher than the tiptop level in the water and sediment regulation of 2005. Because the water was polluted, it couldn't be distributed and caused partly flooding. With the timely and accurate regulation, and air temperature increased, the freeze up section broke up normally. But long lasting low temperature would develop the river freeze up and aggravate danger of the ice jam. That kind of incidents which affect anti ice jam flood deserves much research on it.

## 4.4 Urgent issues of data predictions and emergency repair on anti-ice flood

At present, the ice flood observation method is not good enough for the anti ice jam flood. The ice regime report, ice flood observation and ice flood investigation are still done by manpower. The data is not precise, the responding speed is slow, which affect the decision making of ice flood regulation. Because ice jam floods occur in emergency and are difficult to deal with, so the technique should be improved.

## 4.5 Prodigious contradiction between Yellow River diversion for water supply, water discharge not cut-off and anti ice flood

The Yellow River diversion for water supply cut down the river flow and easy to form small flow freeze up. Once frozen up, stopping the diversion would increase the river flow all of a sudden and pose negative impact to the ice flood control. So we should reinforce the water analysis, prediction and regulation to diverse or reserve the river water and serve the economic development along the Yellow River on the premise of the safety of anti ice flood and no drying-up of the water discharge.

## 5 Anti-ice flood measures

### 5.1 Progress of anti-ice flood measures

Before the foundation of PRC, the anti-flood measure was to place rafts made of trunks on meeting water side of dangerous area for bank protection. When the river flow reached the bankfull discharge, there was no other effective countermeasure except defense by people. That was why the old parlance "If the burst of the Yellow River is caused by ice run disaster, the river officials would not be punished" came out.

In 1950s, ice jam was regarded as the leading factor that might cause ice flood. Icebreaking was a basic method for ice flood control. The narrow section where ice damming could possibly be generated was opened by icebreaking prior to the river thawing. Timely explosion was made in case of the formation of ice damming.

In 1960s, the gradual increasing of flow when the frozen cover broke up was the key factor to cause ice flood. The countermeasure was restricting the channel flow in breaking up period. In 1960, the operation of the Sanmenxia Reservoir offered opportunity for water storage. At the same time, the sluices along the lower river could also be used for water and ice diversion.

## **5.2 Current anti – ice flood measures**

The main anti – ice flood measure is to control the channel water flow, supplemented with breaking ice cover and enhancing ice flood observation and defense. Ensure the ice flood control safety.

### **5.2.1 Utilize reservoirs for integrated regulation and rigidly control lower river channel flow**

Control the lower river channel flow rigidly by utilizing the Xiaolangdi Reservoir in company with the Sanmenxia Reservoir. In the frozen period, it controls the large flow of runoff and leads to thicker ice cap, in the freeze – up stability period, maintain the flow of runoff relatively stable. When the temperature rises up in large range that may cause breakup of the river, lessen the flow and form “mild breakup of ice”. It will bring no harm even if it causes partly ice jam because of low flow of the channel. The Yellow River Flood Control Headquarters make deployment on the anti – ice jam flood work with regulation by large or medium scale reservoirs in the upper and middle reaches, which can guarantee the anti – ice flood of the lower river macroscopically.

### **5.2.2 Enhance observation and prediction of ice jam flood and take regulation measures in time**

In the ice jam flood period, the Yellow River department concerned should be on duty day and night, reinforce ice jam observation, analyze and predict the ice jam tendency according to air temperature and flow, deploy anti – ice jam measures.

### **5.2.3 Diverse water and ice in time and reduce the channel water flow**

When ice jams block water flow and make the water level increase, water and ice are diverted in plan by sluices and diversion works along the river, which can efficiently reduce river channel water storage, ice flood and prevent from causing flood.

### **5.2.4 Break the ice running blocks and ensure ice running smoothly**

In ice flood season, when ice running appears in the lower river, remove bridges holding back ice jam to avoid causing channel freezing up in advance and ice flood influencing the security of the floating bridges. In the river opening up period, when ice jam occurs and influences the anti – ice flood safety, ice jam explosion is demanded to be carried out in time to guarantee ice running smoothly.

### **5.2.5 Make full preparation of ice – flood control and ensure measures well taken**

Deploy and prepare early and fulfill ice jam flood control plan seriously. Organize training for ice flood observation and blasting. Deposit enough anti – ice flood materials, make preparation for the flood diversion of floodway sluice and culvert gates, arrange the migration from floodplain and flood detention area appropriately according to rescue plan. In the ice jam flood period, the Yellow River department concerned should be on duty day and night, reinforce ice jam observation, analyze and predict the ice jam, deploy anti – ice jam measures and guarantee the safety of anti – ice flood.

# Thinking of the Influence of Hydraulic Project on River's Health and its Countermeasure

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**Abstract:** This paper describes the relationships between hydraulic project and river's health, and analyzes the positive and negative influence of the hydraulic project on river's health. On the basis of the analysis of main reasons of its negative influence, this paper puts forward the countermeasure for the harmonious development between the hydraulic project and the river's health.

**Key words:** the hydraulic project, river's health, influence, the countermeasure

As a place for people to live, river has brought disaster to them. Up to now, in order to control flood, exploit the river, and maintain the daily life, people have constructed lots of hydraulic projects. These hydraulic projects have played an important role in the resistance of flood and drought, the maintenance of social and economic sustainable development, the conservation of water and soil resources and the improvement of ecological environment etc. However, the hydraulic projects always have negative effects on the river's ecosystem, even threaten rivers' health directly. Therefore, it's necessary for us to bravely face up to ecological influence of the hydraulic projects, correctly deal with the relations between development and protection, persistently insist on the science development viewpoint. That is, the nature and human being should be developed harmoniously with the aim of maintaining the rivers' health and sustainable development. Meanwhile, we should take all kinds of measures to standardize the human activities, strengthen the social construction of resource saving and environment conservation, strictly act in terms of natural economy rule, and persist in the equal attention to the engineering construction and the ecology protection. Then, the hydraulic project could serve not only for the national economy but also for the ecological construction and protection. Based on "the development according to water resources", the integrated management of water resources, and the harmonious development and utilization, could realize the harmony between hydraulic project and the river, as well as between the nature and human being.

## 1 The relations between hydraulic project and river's health

The relations between hydraulic project and river's health, are essentially those between human being and the river. The relations between human being and the river are basic for the long-term coexistence of the society, and the contradiction between them also is basic for the survival and development of the society. The dependence on the river changes by human being. According to the development process, their relations could be divided into four phases, including the dependence, the exploitation, the over-exploitation, and the harmony. In the primitive society with lower production capacity, human being adapted to the nature passively, primary society with lower productive capacity, human being adapted to the nature passively, and mainly relied on the river for their survival. Along with the the improvement of productive capacity, human being began to develop and make use of the nature simply. Along with the further improvement in the technology and the productive capacity, human being stepped into the construction of hydraulic project, and began to plunder the nature on a larger scale, which causes soil erosion. Consequently, many rivers dry up gradually, and their ecological environments become worsen in order to avenge human being. Then after realizing serious loss of ecological environment, human being start to seek the new harmonious coexistence between the nature and human being.

It is proved that the reasonable and moderate construction of hydraulic project is beneficial to the maintenance of the river's health. Similarly, without necessary hydraulic project, the river also cannot maintain its health. But everything has two sides. Despite of its important functions, it is

also unavoidably for the hydraulic project to have the negative effects on the river. However, so long as the suitable measures are carried out, those negative effects could be reduced or eradicated. We must adhere to the harmonious development viewpoint between the nature and human being, make an overall and scientific plan, and strengthen the management. And we cannot give up the reasonable harness of the river because of negative effects of hydraulic project. In a word, we must integrate the hydraulic project with its ecological construction, because the harness of the river aims to utilize its functions, and maintain the integrality of ecosystem of the basin. Then, this kind of hydraulic project is not only a social and economic project to meet the people's demand, but also is a sustainable and ecological project to maintain the river's health and protect the environment. The comprehensive utilization of hydraulic project guarantees the harmonious development of hydraulic project and the rivers, and eventually realizes the harmonious coexistence between the nature and human being.

## **2 The influence of hydraulic project on river's health**

As a practice of transformation and utilization of the nature, the construction of hydraulic project is in charge of the control, the regulation, the management, and the conservation of nature. The project, with the purpose of reducing and avoiding the flood and drought disaster could meet the demand the economic development of the society, and improve the quality of ecological environment. The hydraulic project mainly aims to prevent the flood and drought, rehabilitate the river course, conserve the ecosystem, generate the hydraulic power, protect the coastal zone, regulate the water resources etc. In a word, the hydraulic project plays an important role in flood control, the irrigation, water supply and electricity generation etc., while influences negatively on the structure and the function of the river ecosystem.

### **2.1 The positive influence of hydraulic project on river's health**

Along with the economical development and the population growth, the demand of water resources increases day by day, and the hydraulic project utilizes and regulates water volume in many rivers. This not only meets the demands of the society, such as water supply, flood control, irrigation, electricity generation, shipping, fishery and traveling etc, but also powerfully impells the economical development and social progress, which realizes the maintenance of the ecological environment and the river's health. It is mainly reflected by the following four aspects: firstly, it is advantageous to the unification of water resources and the reasonable arrangement to improve the regulation of water and sand. Secondly, it is advantageous to fully exert the storage and regulation of the river by the regulation of water resources, which may resist the impact of the floods on the ecosystem. Thirdly, it is advantageous to prevent the zero flow of the river, reduce the water pollution, and improve the aquatic environment. Fourthly, it is also advantageous to the overall plan and utilization for each kind of service function of hydraulic functions, so as to increasingly improve the social and economic development.

### **2.2 The negative influence of hydraulic project on river's health**

Despite of the benefits for the human society, the hydraulic project often brings continuous and profound influence to the ecosystem, at the cost of the nature, the social environment and the land. This has destroyed the original natural ecological balance, and directly affected the natural functions of the river. For the sake of people security and economic interest, human beings unblock in the river, realign a river course, and build dams. This not only obviously changed the basin terrain landform, the rivers natural form and the hydrology silt natural process, but also reduced the diversity of river's shape in the continuities of riverbed and damaged ecological system. Therefore, the simplicity and uncontinuity of rivers shape resulted in the decrease of the aquatic biota and the degeneration of the river's ecosystem, the dam-fall and draft immigrates. In brief, it led to some aspects: one, the influence on the nature. The project construction will change the hydrology condition, flush the silt change to the waters bed bottom shape, and influence the water body, the



microclimate, the earthquake, the soil, the ground water, the zoology and botany, the waters in the bacterium algae, the fish and its the aquatic, even the landscape and the rivers, and the social environment etc. In a word, the project construction greatly influences on the population migration, land utilization, crowd's health and cultural relic historical site as well as the decreasing of the living quality and degeneration of human genes.

### **2.3 The reasons for the influence on the ecosystem**

The negative influence of the hydraulic project on the ecology is objective, and the reason for it can be stated by four aspects; firstly, it is project's own shortcomings. The inherent characteristic of hydraulic project technology is a root to produce some ecological problems. That is, any hydraulic project or any ecological project actually has certain ecological question. Secondly, it is caused by the limitation of the human's understanding and the technical level. The people gradually enhanced the understanding of the natural along with the technical development. however, under the certain space and time condition, the technical level and understanding to the natural is limited, which led to people's insufficiencies of understanding to some ecology problems. Thirdly, human being is lack of self - discipline due to the overuse of the nature. As for the hydraulic project, it has surpassed the bearing capacity of water resources which, thus initiated many ecological environments question; fourthly, it is caused by the lack of high level supervision and management, although the people have the understanding to some ecological problems of hydraulic project.

### **3 The strategy and countermeasure to the harmonious development between hydraulic project and river's health**

Development is the inevitably request for the social progress and the eternal topic for human. The social economy needs the water resources, and the water resources effectively supplies for the hydraulic project. Therefore, we should persist in scientific development viewpoint and regard the river's health and sustainable development as a goal or a center task for the harmony between the hydraulic project and human being. Furthermore, we should manage everything strictly according to the natural economic rule by unification, law and science. We should adhere to the principle of "protect firstly, develop reasonably, and development according to water resources" to avoid the mutual disturbance, strictly implement the total control of water quantity, and reduce pollutants to make sure the harmonious development between the river's water resources and the ecosystem carrying ability. Besides this, we should strengthen the scientific management, to improve and perfect hydraulic project plan and the design technology, and to change the technical method for the use of the nature. We should study and utilize the method and the measure for the integrate between the nature, the river for the harmonious evolution between the human society and the natural system. The hydraulic project can pay more attention to maintain the ecosystem health. In conclusion, we should take great consideration to make sure the diversity of the river especially the ecological functions, with suitable measures, such as technology, economy, administration, law. Then, the hydraulic project could play a unique role to restore ecosystem, protect the wetland, compensate the ground water in the ecosystem, beautify urban environment, and improve water quality and so on. In addition, we should protect the river to realize the harmonious development between hydraulic project and the ecological environment.

### **3.1 Designing an overall plan of the basin and acting according to objective rules**

As the basis of the arrangement, the development, the use, the saving of water resources, the river overall plan is the guide to the basin coordinated development and the maintenance of the river's health. Because the development of the basin usually involves different administrative aspects, we should consider not only some economic technique problem, such as the development, layout, scale, way and succession of the water resources, but also the demand of ecological conservation in the basin and the region. We should persist in the science development viewpoint, on basis of human being as the core, the harmonious development between man and nature, overall

planning, comprehensive consideration, the effective management. This deals with some contradiction, such as benefit and harm, the development and protection, the whole and partial, the long – term and short – term development, as well as the proper arrangements for flood control, water supply, electricity generation, shipping, ecological construction and the environmental protection and many other tasks etc. And we also should insist on the science option to engineering construction plan, including the dam project, in order to make a scientific and reasonable layout for hydraulic projects. We also should assess the influence of implementation of the river plan on the environment. That is, before the decision – making plan of project, the ecological environment conservation should be included in the basin development target, for example, which sections of the river are unfit for the development; which sections of the river are fit for the reasonable development etc. In conclusion, the option, the construction and the operation of the project should actually demonstrate the benefit for the ecology, the economy and the society. Another thing we should focus on is the strengthening of the management of the government function to the water project. For example, the plan for environment assessment should entrust to the specialized organization with special experts; the social public opinion should be obtained widely; the government should public the options to the society and accept the entire supervision by the society so as to strictly build project according to the objective law, maintain the river 's health, promote harmonious development between the nature and human being for the eventual social and economic sustainable development. .

### **3.2 Integrating ecological environment into every loop of hydraulic project to realize an ecological project**

In terms of the social development viewpoint, the harmony between man and nature, or the principle of ecological environment conservation should be put into practice in the plan, design, construction, management of hydraulic project. And we should put the environmental effect assessment into the implementation program of hydraulic project, in order to the reforme the present hydraulic project construction program as soon as possible. That is, in the itemized written proposal stage, we should guarantee the project implementation environmental effect assessment, and propose the measures for the environment recovery and the society compensation, and public the opinion to the society. In the project feasibility study stage, we should carry out the comparison of project plans for ecological environment influence so as to select some rational technical and ecological project plans. In implementing the projects to the rivers and streams lake by the government, we should maintain the natural form of the rivers and lakes as much as possible (including it 's vertical and horizontal cross section), or restores its diversity. We should be prudent to the cuts and the transformation of the river. In rebuilding rivers embankment plan, we must stretch the embankment spacing as far as possible, or take the embankment backlash measure for the project to remain the certain space for the flood and strengthen lateral connectivity of the rivers to provide the refuge shelter for the fish and the amphibian. Meanwhile, the diversity of the cross section of river shape should be maintained to arrange original natural cross section shape of the river. In the project preliminary design stage, we should propose the measures to reduce influence on the ecological environment in order to create the condition for the plant growth and the animal perching, especially for the fish to spawn as well as the refuge shelter for the birds and the aquatic habitats. In the project construction stage, we should firstly take the ecological environment technology measure, and pay more attention to the local natural material of the bank slope for the river course protection project due to their advantages to the plant growth. After assessment project stage, we should introduce after – assessment influence on the ecological environment, establish the monitoring system and the feedback mechanism for the project environmental effect. The hydraulic project facility must focus on their relationships between the nature and human being, retain natural esthetics value of the river and the lakes. The new reservoir project requires fully to prove advantages and disadvantages because of the changes of the river 's ecosystem by reservoir construction. Through the project measure, the biological measure and the management measure, we should give ecological compensation to the dam construction and river development, and try our best to avoid and reduce forcing by dam to the river ecosystem. We also should actually strengthen

the standardizing, modeling management of the hydraulic project to beautify the overall project, and to make it suitable site for antiflood, urgency transportation, and ecological beauty.

### **3.3 Building a cooperative technique mechanism and a scientific technique support system**

The hydraulic project involves many disciplines, including water conservation, ecology, biology, environment, geography, hydrology etc. Therefore, the new cooperation technique mechanism with multi – discipline should be established so that we could solve the technical difficult problems soonly to build ecological influence assessment system of hydraulic project. Also we should formulate quantitatively the assessment standards, the optimum project to its ecology influence, and the suitable economical technique and the ecological environment benefit assessment target system of hydraulic project. Then through self – recovery and the self – purification of the river’ s ecosystem, we can develop and the promote “ecosystem determines the technology to reduce water pollution”, and “economical practical technique” for the development of the artificial wetland, the biological land, ecology floating island; Besides this, we should develop ecosystem health assessment, forecast the constructed reservoir to strengthen the investigation into the storehouse district biota, and pay more attention to the restoration of “degeneration of reservoir ecosystem” and “nutrition control”. In addition, we should study and grasp the rules and approaches, such as the evolution of the rivers, the silt migration, the zoology and botany diversity, climate change, immigration and so on, so as to prevent and reduce the negative influences to the river’ s ecosystem by the hydraulic project.

### **3.4 Building and implementing an ecological compensation mechanism**

In order to prevent and alleviate negative ecological effects to rivers by the hydraulic project construction, we should establish and practice the compensation mechanism for ecology as soon as possible, further consummate the relative policy and regulations, positively explore “cost finding and the compensating process for ecology loss” on basis of the actual national condition. And we should develop the value and quantification assessment for the river’ s ecological services, and eventually bring it into the national economy calculation system by the form of law as the basis for the policy – making of water and electricity project on a larger scale. This can comprehensively measure the loss and benefit of the social economy and the ecosystem service function by the project, in order to avoid the short – term behavior for the direct economic efficiency. In the aspect of dam construction, we should implement the principle of “who harms, who compensates”. The owner of dam project is responsible for ecology compensation, and the compensation scope should not limited to the downstream of the river but to the entire basin. Compensation time should be consistent with the dam life, and the calculation of expense should be based on the loss of the total value of the river’ s ecosystem service function. And we should also formulate the rules and regulations of the ways of compensation. That is, the hydraulic electronic power station should adopt the biological judgments method to the survival in the ecologic circle for a long term to reduce the losses caused by “reduction of the power generation quantity”. As a way of compensation, it should pay part of funds from electricity generation benefit by the hydroelectric power station to the long – term ecology compensation and protection, so as to improve immigration production living condition and urge the engineering project owner to adopt more measure for ecological compensation. So, we can reduce the loss of total value in service function, effectively alleviate the forcing of rivers ecosystem to make the ecology compensation gradually tends to the standardization, legalization, and scientification to maintain the ecological balance.

### **3.5 Implementing the participation of the public and strengthening the social surveillance**

In the rivers development, we must improve the policy – making mechanism for the public participation, optimize the systems such as assessment proof, the expert assessment and public hearing to increase the transparency, which can issue the related information promptly, really, and comprehensively. Also we should public channel for the related benefactor and public to express

benefit and the participation in decision – making, and widely solicit various opinions from related benefit party. Besides the social public participation should be implemented in the whole process of the project, the plan design process should focus on the public decision – making, the balance of all benefits parties. Meanwhile, we should strengthen the intrinsic mechanism construction to form the scientific and effective mechanism – water benefit coordination system, the expression demanding mechanism, contradiction mediating mechanism, the rights and interests safeguarding mechanism. Furthermore, we should strengthen the public opinion surveillance to give the rewards to those reporting randomly constructor and occupier promptly, and trace the bad behaviors, including each kind of misdeed, to maintain the river’s sustainable development.

### **3.6 Strengthening the protection and the management of river course to maintain its sustainable development**

We must practically strengthen the management of river course in terms of the maintenance of the river’s health, persist in the equal place for both development and protection of the environment, strictly check basic construction examination and approval pass for the river course management. In items of some projects near the river, like river – crossing, river – blocking, dike – putting etc, we must carry on the appraisal analysis to flood – prevention influence to establish the plan for the conservation of water and soil and carry on the water resources proof for the water – taking project. At the same time, we should strengthen the management of the items of basic construction in the river course, and projects like construction for the bridge and the wharf and other buildings for river – crossing, river – blocking, the nearby river project, as well as lay – down for the cross river pipeline cable line, must conform to the national stipulation of flood prevention standard and other related specifications, and they can not affect, invade, and destruct the basic project facility for embankment, river bank, hydrographic survey and hydrology geology monitor and make related design and plan according to the authorized material such as the flood prevention appraisal, water resources proof report, conservation of water and soil plan etc, to carries out each item to compensate the remedial treatment expense and guarantees the water and soil can not be drained, and the water quality will not be polluted, and increases the law enforcement. We should, furthermore, earnestly cleans up the constructed projects in the river course management, to register those which confirms to the river course management stipulation and promptly discard those which does not conform to the basin flood prevention plan and other requests, and which is unable to be mended after the proof to the items of basic construction. We should strictly destroy the illegal unlicensed building in the scope of river course management and put an end to the plundering the river with the behaviors of water resources behavior to maintain the sound river course management order and safeguard water resources sustainable development for good ecological environment.

### **3.7 Strengthening the unified regulation of water resources and building water – saving society for the reasonable utilization of water resources**

We should vigorously strengthen the construction of the antifouling society with water thrift, establish the water resource management system with the combination of the total quantity control and quotas management and the reasonable mechanism for the water price to form “saving water society movement mechanism” with government regulation, market guidance, public participation. We should guarantee the right of water using ecology disposition of the rivers through the implementation of taking the basin as the unit with water resources unified management, unified plan, the unified dispatching to perfect the system for water utilization and try to realize the restriction and limitation to water use for the social economy and limit the development of the water resources than less 40% so as to avoids resources wasting and the pollution harm put stress on the assignment and management of water use. And we also should establish an institution governed by the basin unified organization, by the region integrated water service organization and by the unified mechanism of market disposition, and by the adjustment of transaction system between water – taking right and pollutant – dumping power. In conclusion, we should strictly implement water – taking and pollutants – dumping licensed system and intensify enhances space and time regulation

ability water resources, and further perfect region plan management to the water function; meanwhile strengthen monitor mechanism to the rivers ecosystem and establish the protection mechanism to water – used ecology. Besides, we should unceasingly perfect the project and the non – project of flood prevention and drought combating system with persistence in “protection in the development, development in protection” and establish water resources conservation system, such as the total quantity control of dumped pollutants, management control by norms, water quality monitor, early warning for exceeding of the allowed figure, excessive penalty etc. In addition, we should strengthen the government supervising and managing, speed up the facility construction for sewage treatment, positively levy the sewage treatment expense, and practically enhance the sewage treatment efficiency and benefit. Furthermore we should standard humanity moves taking the bearing capacity of water resources and environment as the restraint so as to adjust the region economical layout and the industrial structure, vigorously develop the circulation economy, plan and coordinate water using for life, ecology and production overall to unceasingly enhance the water – used efficiency and benefit to guarantee water – supply for the rivers ecology to realize the harmony between man and water.

### **3.8 Strengthening water and soil conservation to protect ecological environment**

The goal of the rivers ecology construction is to restore the health and sustainability of the ecosystem with the key point of the biological habitat construction and the rivers natural hydrology condition improvement to guarantee the minimum water demand for the river ecology and restore the multiplicity of the biota, eventually to create the condition for species and energy current in ecosystem, the nutrients circulation as well as the biological competition so as to maintain ecological equilibrium. Besides we must persist in the principle of “prevention primarily, the protection the first” to strengthen the preventions surveillance to avoid the man – made destruction. As for the ecological seriously – destructed rivers, we should take the measures of saving water, anti – dirty, adjustment to restore and nurture water resources with the plan to carry on making up the water for the wetland. In the area where ground water overdeveloped take the measures of well sealing, pick – limiting to protect the ground water. Regarding such vulnerable area in ecology as soil erosion, the attentions should be given to the nature’s self – repairing ability to implement the strategies of “back from agriculture to the forest” and “herds forbidden in the mountain area” and so on herd; in the serious soil erosion area, the dam project should be constructed in flood area to retain the silt and plant crops to develop the economy; in the pastoral area, we should do well in hydraulic construction to develop the irrigation for the fodder place; to the natural prairie we should take the measures of herds – forbidding, rotation – grazing and herds – resting to protect and restore the prairie; in the hydro – electric resources rich mountainous area, we should positively develops the small scale hydraulic power station to enable the farmer to solve the energy problem so as to reduce to the forest destruction. We should also establish water conservation safeguard system for the maintenance of ecological environment security to distribute the water use reasonably and reduce the human’s activity influence ecological environment the lowest degree.

### **3.9 Strengthening the scientific regulation for a group of reservoirs to fully exert their comprehensive benefits**

On the basis of the full use of the ways of the and management for the constructed hydraulic project, management, we should put the adjustment of the reservoir into the whole river regulation, improve and restore the ecological water system of the rivers and lakes according to the demand of river’s health and ecological environment so as to effectively display the function of storing and regulation of the hydraulic project to adjust the water and sand at the right moment to improve ecological environment as well as intensify the ability of flood resistance and restore the rivers’ natural function. For example, since 2002, we give water and sand adjustment five times so as to make the downstream ability for river flowing increase from 1,800 m<sup>3</sup>/s to 3,500 m<sup>3</sup>/s to improve the river ecological system. In satisfying man’s demand, the reservoir dispatcher should give proper attention to healthy demand of ecosystem to overcome the adverse effect of the still water, the deep

water on the biota. Eventually we can improve the ability of self – cleaning and self – restoration of the reservoir through the reasonable structural design for the biological construction and the aquatic biologism so as to fully display the social economy and the ecological environment benefits and maintain “the health of reservoir”, enhances “the life of reservoir”.

### **3.10 Strengthening the management and development to build a reasonable development system of the water and the electricity**

The water and electricity project is a clean energy construction project. We should earnestly carry on the basin development plan to make development plan for water and electricity obey the overall basin plan. Specifically speaking, the clients for water and electricity development who has not formulated the basin plan, or has not attained the authorization can not carry on the development construction for water and electricity. And we should thoroughly put end to “four does not have” the power plant, namely “without items, without design, without management, and without approval, and the average development rate of water and electricity resources should be less than 70% ~ 80%”. And we also should take consideration of the environmental effect appraisal work of the water and electricity development plan and establish water, electricity development system with friendly environment, and strengthen the standard management of the water and electricity development with examining and approving the water and electricity project strictly and legally, so as to cease the disorderly development and persist in the principle of “first appraisal, then construction” to optimize project design and put the measure of prevention and control of pollution and the measure of the ecology protection into practice simultaneously. At the same time we should solve the environment and the immigrant problem properly, and strengthen project environment supervision clearly about the environment management responsibility. And we also should fulfill the immigration placement work well with the enhancement of the ecologization of basic construction items the water and electricity to standardize project construction and operation of water and electricity eventually in order to optimize the management of the reservoir function to reduce and eliminate the ecology influence and realize “double wins” between the rivers development and the conservation.

## The Successful Experiences of Ecology Self – rehabilitation in Sweden and its Apocalypse for China

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**Abstract:** In recent years, China has paid close attention to the improvement of ecology self – rehabilitation, a series of measures have been adopted, and good effect has been made. But these achievements are far from enough for China where the soil and water loss is so heavy. More hard work should be done to promote the sustainable development of this project. In recent decades, Sweden has achieved huge success in eco – environment protection and rehabilitation by carrying out a lot of effective measures. By introducing the experiences of Sweden, some viewpoints which can be useful for n China were presented.

**Key words:** ecology self – rehabilitation, soil and water conservation, experiences, Sweden

Sweden, with an area about 450,000 km<sup>2</sup>, and population about 9.04 million, is located on the east side of the Scandinavian Peninsula in North Europe. It is bounded by Finland to the northeast, the Gulf of Bothnia and the Baltic Sea to the east, North Sea to the southwest and Norway to the west and northwest.

In Sweden the terrain from north to south are narrow and long, the topography from northwest gradually inclines to the southeast, the peak in the east side of northern Scandinavia Mountains is about 2,117 m high, and hills and plain distribute in the south part and coast. Approximately 96,000 Lakes spread all over the country, accounting for 8% of the national total area. There are more than four main rivers in the country, and the water resources are rich.

About 15% of land in Sweden is located in the Arctic Circle, the climate between the north and the south is totally different, and the most areas belong to the subfrigid zone. The south part is in the subordinate temperate zone with marine climate, and the north part is covered with snow for half year, the sun can hardly be seen more than one or two month in winter and there is no night in summer for one month long. The climate is temperate in the middle and south part because of the warm current of the North Atlantic Ocean and the Baltic Sea. The average temperature in February is –12.9 °C low in the north and –0.7 °C low in the south, and in July is 12.8 °C high in the north and 17.2 °C high in the south. The annual precipitation is about 555 mm.

The scenery in Sweden is elegance. The forest land occupies more than half of the total land area. Forest, iron ore and water conservancy are Sweden's top three nature resources; especially the iron ore is well known for its quality in the world. Domestic transportation and communication is well developed, the quality of the labor force is high. The main industry is metallurgy, machine manufacture, timber machining, paper making, ship building, automobile making and so on, of which the alloy steel smelting and the special steel are famous. The private enterprise occupies 90% of the industrial production. The timber machining occupies the quite important status in the country economy, the agriculture only accounts for 2% of the Gross National Product and the employment opportunities. The main crops are oats, wheat, barley, potatoes, and vegetables and so on. The food supplies are self – sufficient, and the animal husbandry plays very important role in the agriculture.

### 1 Environment situation and main problems in Sweden

Sweden is a sparsely populated country with vast forests and tens of thousands of lakes. Air

quality and drinking water quality are better than in many other European countries and there are few health problems caused by poor environment. Soil erosion is slight. The Swedish loves flowers, bird and other wild life, and deeply loves the nature. People there like open country activities in the leisure time, such as hiking in forest and field, picking the wild fruit and the mushroom, swimming in the sea, lakes, boating, fishing and so on. However, new findings have led to a reassessment of health impacts. A number of environmental factors are now viewed more seriously. These are as follows:

(1) Factors that influence environment quality, such as particulates, ozone and noise. Other problems maybe harmful to health are radon in indoor air, mercury and organic toxins in some foods.

(2) Although greenhouse gas emissions in Sweden were no change in recent years, per capita emissions of carbon dioxide are lower in Sweden than that in most industrial nations (approximately one third of per capita emission in the US), compared with developing countries, however, Sweden releases large quantities of carbon dioxide; per capita emissions are some six times higher than the average in Africa.

(3) The predominant methods of electricity generation are hydropower and nuclear power. Transportation is still largely based on burning oil, coal and other fossil fuels. These sources fuel accounts for some 17% of domestic heat energy supply. Emissions of sulfur and nitrogen compounds by burning mineral fuels have acidified soil and water throughout much of Sweden. Even though only a minor part of this acidification is attributable to national sources, the major part derives from emissions in Central Europe and the Great British Isles, and acidic precipitation is now diminishing, thousands of lakes are still so acidified that they have to be limed regularly to enable sensitive species to survive.

(4) Nutrients such as nitrogen and phosphorus from sewage discharge and excessive fertilized farmland accelerate the growth of algae and other vegetation in lakes, watercourses and coastal waters. The Baltic Sea is significantly affected by eutrophication; the high concentrations of nutrients cause excessive organic production.

(5) Over-fishing and eutrophication are the main threats to species diversity in the sea and along Swedish coasts. The characteristically brackish environment of the Baltic Sea is home to no more than 80 species of plants and animals in central areas. The number of species rises to around 1,500 in more open, saline sea areas such as the northern Skagerrak on the north coast. Cod stocks are threatened in all areas. The same situation happens to herring in the Gulf of Bothnia and eel in the central Baltic.

(6) Even though Sweden has a low population density, there have been extensive changes in land use since 1920s, particularly in the agriculture sector. There are now fewer and larger farms; there is less pasture land, and valuable wetlands have been drained.

(7) Because exists problems in the forest management, 5% ~ 10% of all species (more than 4,000 species) in Sweden are endangered, including large carnivores such as the wolverine and the wolf. Sweden's waste management level is higher than the average level of European, Metal emissions to the air from Swedish industry have been reduced to the levels in 1970s, and lead emissions from road traffic have been eliminated completely. Deposition of lead and cadmium has fallen by at least 70% throughout Sweden over the last 20 years.

## **2 Method and experience of environment protection and rehabilitation**

In recent years, along with the awareness of the importance of environment protection, Sweden has taken many measures to ensure the sustainable development of future society, which are as follows.

### **2.1 Building up sustainable development environment stratagem**

Sweden government has been concentrated on building the country into "a green welfare



state". In order to realize this strategy, they adopted all kinds of method such as technology, engineering, and planning and so on, simultaneously seek the positive energy and environment policy. Sweden government believed that, construction of the green welfare state will be able to promote the national effective use of resources, realizing innovation development, increasing the employment opportunities, quickening economy grows, improving social welfare. In "the green welfare state", the economical development will harmonize with the social justness and environmental protection, the interest and benefit of this generation will unify with the descendants.

The ultimate goal of Sweden government policy is to realize the sustainable development that means all national political decision must take the long-term economy, society and environmental effect into consideration. In the ecological environment aspect, Sweden government's goal is described as "hand over a society to the next generation in which the main environment problems have already been solved".

To ensure the entire social to implement the national environment policy in various aspects, Sweden Congress passed a proposal that emphasizes all government institutions, the companies and other organizations in its domain should share the responsibilities in the context of environment problems.

## 2.2 Constituting environmental quality objectives

In the past many years, Sweden Congress has accepted nearly 200 different proposals about environment construction goals in different legislations. These goals are mostly complex and difficult to understand. Therefore, the country begins to establish a new ecological environment target system, in which comprehensive nature of the targets is emphasized on one hand, on the other hand the targets should be achievable and the most basal environment quality request should be considered.

In 1998, the Sweden Congress approved unanimously the country ecological environment quality goal which was composed by 15 indexes (in November 2005 add one item, presently totally 16 items). The 16 national environmental quality objectives are shown below: ① Reduced climate impact; ② Clean air; ③ Natural acidification only; ④ A non-toxic environment; ⑤ A protective ozone Layer; ⑥ A safe radiation environment; ⑦ Zero eutrophication; ⑧ Flourishing lakes and streams; ⑨ Good-quality groundwater; ⑩ A balanced marine environment, flourishing coastal areas and archipelagos; ⑪ Thriving wetlands; ⑫ Sustainable forests; ⑬ A varied agricultural landscape; ⑭ A magnificent mountain Landscape; ⑮ A good built environment; ⑯ A rich diversity of plant and animal life (new added in Nov. 2005).

The 16 goals described the natural and cultural environment prospects after Sweden achieved ecological environment sustainable development. The purposes to establish these goals are to analyze and study the state environment problems, identify the main contents of ecological environment work, coordinate the environment work actions between different departments and projects, simultaneously enhance the environmental awareness, monitor environment tendency.

The majority objectives are designed to be achieved in 2020. Only four goals including reduced climate impact, the non-toxic environment, the sustainable forest and zero eutrophication are possibly difficult to realize at the appointed time because of influence of the international cooperation and ecology rehabilitation cycle.

Above various targets specially are responsible to monitoring and evaluation by the Sweden Environment Goal Committee.

## 2.3 Setting up high efficient environment management institution

Swedish government has 1 Premier's Office, 1 Office of Administrative Affairs, 1 European Union Permanent Representative Deputy and 9 professional departments, including the sustainable development department responsible to dealing with the problems on ecological environment, energy, construction work and resident surroundings. It also has the overall responsibility for

coordinating the government's work on sustainable development. The Department of Sustainable Development is in charge of the country sustainable development strategy planning, energy and environment policy making, atmospheric policy, environment and health, the chemical material policy, ecological environment quality goals, water conservancy and the sea, natural conservation and the biodiversity, the ecological environment law, European Union and the international cooperation and so on. The Department of Sustainable Development is responsible to preparing all related environment policies decisions – making, but the other government departments must be responsible for the environment consequences in their own domain.

The environmental, social and economic dimensions of sustainable development shall be pursued in a coherent manner, both within Sweden and in relations with partners around the world.

Four strategic challenges have priority in the revised national strategy for sustainable development: building sustainable communities, encouraging good health on equal terms, meeting the demographic challenge, and encouraging sustainable growth.

## 2.4 Enacting integrated environmental acts

Sweden pays great attention to environment protection legislation. In 1969, Sweden had its first environment protection law. After 1980, 15 rules have been formulated. 15 existing environmental laws were modified and State Environment Protection Acts was put into effect in 1999.

The Acts contains several “general rules of consideration”, i. e. factors serving as a basis for decisions by regulatory and licensing authorities. These rules include the precautionary principle; “polluter pays” principle and “product choice principle”, which impose an obligation to choose a less harmful substance if such an alternative is available.

The Acts provides that commercial and industrial operations must use the best available technique, and that operations must be located so as to cause minimum harm to human health and the environment. It also establishes that the party causing the damage is liable for site remediation.

The Acts stipulated further responsibilities and obligations of all units, individual on ecological environment protection, emphasized government's surveillance function, requested that all national economic and society activities must be carried on under the new Acts.

In 1995, after Sweden became the member of European Union nation, its ecological environment protection policy and regulations have been served as the common criterion model. Sweden also positively participates in the international environmental protection work. In order to guarantee implementation of the Act the, Sweden set up the environment court in 5 regions of the whole country (including water court). The court specially tries the environment case. At the same time, the Swedish government encourages the public to participate in supervise of the environmental protection.

## 2.5 Determining general rules on environment protection

According to the Act, General rules of environment protection are shown below:

(1) Principle of Environment evidence inversion. Business owners must provides evidence to prove their production or construction activities conforming to the legal requirement and certainly no negative influence to the environment, but any other person affected by the environment has no such duty.

(2) Principle of knowledge and ability. Business owner must possess the necessary environment knowledge and ability that correlated with enterprise nature and scale.

(3) Prevention principle. Taking preventive measures is to reduce or eliminate ecological environment harm and risk from enterprise management. This principle is the core of Sweden environment law.

(4) Best practical technology principle. It refers to the most feasible technology must be taken in the process of construction, operation and production to protect the ecological environment.

(5) Principle of reasonable site selecting. The selected sites for construction and operation

should be conform to the ecological environment and other related requests.

(6) Principle of polluter pays. Any person who causes the ecological environment influence must pay for the related prevention and treatment measures to meet the legal request.

(7) Principle for resources management and ecology circulation. This principle requests the business owner must take effective action to guarantee the effective use of the raw material and energy, and reduce consumption and the waste discharges. The solar energy, wind power, water power and the biological renewable energy should be taken as the first choice.

(8) Product substitution principle. Chemicals possibly harmful to the ecological environment and the human health should be avoided selling and using, products with low poisonous substance or harmless should be use instead to reduce such harm.

(9) Feasible principle. When considering environment benefit, other benefits also must be considered. For instance, implementation of the environment measures cannot limit person's freedom.

(10) Forbidden principle. The development and management activities still can create severe environment problems even adopts preventive measures in accordance with related law are forbidden.

## **2.6 Exercising strict and effective ecological protection system**

### **2.6.1 Environmental permit system**

A lot of development or business activities need to apply for licenses otherwise cannot be done. According to Environmental Act, about 6,500 kinds of development or business activities harmful to the environment require licenses. Licenses are issued by offices of provincial environmental permit or environmental court. Law enforcement agencies can propose reconsideration of licenses issuing decision, the applicant, labor organizations, affected residents and civil organizations may also suggest reconsideration of licenses issuing decision.

### **2.6.2 Enterprise – controlled system**

Enterprise self – monitoring system is a small scale environmental management system for law – abiding enterprise to meet the basic standards and requirements. Swedish Environment Act requires enterprises to establish a self – monitoring system, and defines the monitoring responsibility and obligation of enterprises. The law requires enterprises must conduct environmental audits, and make the examine process documentary. If emergencies harmful to human health and ecological environment happen in firms, the enterprise functionary must immediately notify the government administrative departments. It's necessary to keep the results, methods and detailed information from enterprise self – monitoring for five years, and the law enforcement agencies have the right to examine all the relevant records and documents.

### **2.6.3 Enterprise annual environment reporting system**

The legal system has definite stipulations on corporate environmental report. Annual Environmental Report mainly includes the measures taken, the benefits achieved, compliance of standards and meeting the requirements of the permit. Annual Environmental Report should be submitted to the law enforcement agencies and available to the public. The juridical person will face litigation if violating the requirements of Annual Environmental Report.

### **2.6.4 Law enforcement supervision system**

All development and business activities harmful to the ecological environment have to be subjected to environmental enforcement agencies supervision and inspection. Environmental enforcement agencies are responsible to formulate and carry out supervision and inspection plan. The county public health and environmental management committee is in charge of eco – environmental supervision and law enforcement. there are two different types of on – site supervision and inspection, one is to examine the internal self – monitoring system, another is to focus on

examining enterprise technical measures.

## **2.7 Taking economic policies in favor of ecological protection**

Sweden adopted positively various environmental and economic measures like environmental taxes, fees to protect ecological environment. World OECD, in its 2004 report, concludes that Sweden has implemented more than 70 market – based economic measures, which is higher than any other countries in the world. Sweden levies annual environment – related taxes reached 68 billion Swedish krona (7 billion euros).

Taxes and fees can provide investment for environmental management and resource protection; on the other hand, owing to the tax impact of the cost of production, farmers will try to reduce use of pesticide and fertilizer, increase use of pigs, cow manure and other organic fertilizers, consequently reducing pollution from pesticides and chemical fertilizers, increasing soil organic matter, enhancing soil fertility, and forming an ecological virtuous circle. Industrial and investment fields have been able to guide so that construction activities can be done more environmental friendly. Taxation policies and regulations not only protect the interests of consumers more efficiently, but also effectively promote sustainable development of ecological environment protection.

## **2.8 Promoting ecological protection technology research and development vigorously**

Concerning ecological environment technology, Swedish defines it as all technology can minimize environment harm than any other alternative products or methods. Development of ecological environment – friendly economy provides huge potential for environmental technology. To improve the technology for prevention and resolution of the ecological environment problems, Swedish government has been strengthening cooperation in different aspects of society, such as business, universities and research institutions, Non – governmental organizations and the public work together.

In 2005, Swedish government decided to set up the Swedish Environmental Technology Commission (SWENTEC). The Commission coordinates public development projects from all environmental technology fields, which involving research, exploitation, market development as well as export promotion. In addition, the Commission will also support cooperation of regional networks from industry, research and development organizations and local authority departments. In the first year of the Commission, Swedish government provides 1.1 million for its activities.

Swedish Innovation System Bureau (Vinnova), combines technology, communication closely with work and living research and development. Its objectives is to establish an efficient innovation system and promote sustainable growth through subsidizing scientific research and technology development.

Swedish Business Development Agency (Nutek) is the national industrial policy organization, as well as a pilot center for entrepreneurs, business development and regional development. It is responsible for running a business development plan to improve environment. The plan focus is to support middle and small enterprises in their production and business development to enhance competitiveness in taking consideration of environmental issues under the premise. The agency introduced environment management projects to small enterprises before.

Swedish Trade Commission, has a project called Swedish Environmental Technology Network, mainly promote and support new business opportunities in the field of environmental technology. The network includes more than 600 consultants and vendors, connect closely with environmental technology industry such as water supply, waste water treatment, waste management, air pollution control and renewable energy, and provide their markets.

## **2.9 Protecting ecological environment in different field successfully**

### **2.9.1 Natural environment protection**

Biodiversity in Sweden is abundant, many animals and plants are totally depend on wetland ecosystems, some plants and animals in their crucial life stages use wetlands. Sweden wetlands total

area of about 93,000 km<sup>2</sup>. kilometers, accounting for 20% of the land area.

Sweden in the 1980s carried a wetland resources survey to fully understand and hold the wetland resources, prevent the further destruction of wetlands as well as comprehensive evaluation of wetland protection. Subsequently, the State established a wetland database, formulated “wetlands conservation planning”. Now, Swedish government has stopped unreasonable wetland development, and banned draining of wetlands.

According to authoritative wetlands data completed in 2004, wetlands in Sweden are currently in good condition, which showed the results of wetland protection are remarkable. On this basis, in 2005, Sweden began to draft a national wetland and wetland forest protection and management strategies. Wetland management in Sweden is going forward in more elaborate direction.

### **2.9.2 Ecological protection in agriculture and non – point source pollution control**

Ecological agriculture is kind of modern agriculture development model with a reasonable ecological function and good circulation that use of ecological principles to combine modern science and the best of traditional agricultural technologies. Sweden is at the world’s leading position in ecological agriculture. The main objectives of ecological agriculture are: produce high – quality food, maintain lasting fertility of land, enrich crops and animal species, restrict non – renewable natural resource utilization, make farmers managing ecological agriculture maintain a reasonable income, reduce environmental pollution, and so on.

Ecological agriculture in Sweden developed quickly. Main practices are: use of natural fertilizers (cattle, sheep, swine manure); manual weeding; four – year rotation to maintain soil fertility and reduce pests. The features of ecological livestock are: outdoor ranching; feeding ecological fodder; Livestock epidemic prevention – oriented.

Sweden in control of water pollution from living and industries has achieved remarkable progress. Nowadays they turned their attention to reducing water pollution caused by agriculture, which is non – point source pollution. Owing to the characteristics of agricultural production, it is very difficult to control agricultural sewage drainage. Control of agricultural sewage largely depend on farmers land use and the production plan. Therefore, agricultural policy affected farmer’s decision – making and environment policy controlled agriculture water pollution must be closely integrated.

In order to encourage farmers to protect the environment, Sweden implemented a series of deep – seated reforms in Agricultural policy under EU initiative. These reforms include: reducing support to the prices of some agricultural products, restricting certain agricultural production, restricting livestock maximum number. In addition, Swedish government encourages farmers to take kinds of production model that meet ecological protection requirements through comprehensive agriculture and the environment policies. For example, the government offered a certain amount of subsidy for farmers who are active to implement soil conservation tillage (e. g. grass and grain intercropping), reduce livestock rearing and fertilizer and pesticide use, introduce organic fertilizers or no longer engaged in agricultural production according to the cost of production.

### **2.9.3 Water environment protection**

Water management in Sweden mainly complies with EU “the European Water Framework Directive. The framework requested EU Member States to identify the basin and water management zones, take river system as a whole to manage. It also called on the Member States to designate a relevant departments responsible for the implementation of relevant provisions. In order to achieve the management objectives “the water must be keep in a good ecological state by the year 2010”, EU Member States also need to work out corresponding implementation plan. Meanwhile, the framework also requires all member states levy water rates reflecting its true cost from families, farmers and industrial water users in 2010, including freshwater access and distribution and sewage collection and disposal. It further asked no cross – subsidies between families, industrial agricultural water use, and the government must ensure that all families can afford to basic water consumption.

According to the requirements of EU Framework Directive, Swedish central government and provinces, Cities cooperated to formulate regulations more detailed on water management. In April 2004, Sweden set up five water management basin agencies, in which an administrative departments in each province has been designated as water management authority responsible for management of local watershed water quality.

In 2005, Swedish government designated the relevant departments to draft action plan to restore the rivers or streams with high conservation value or potential value. It is estimated that about 25% of these rivers or streams ecology will be restored by 2010.

In regards to restoration of the river, stream and lake ecology, Sweden generally use measures combining chemical, physical and ecological methods. Chemical method is to lime in water, physical method is to remove the major barriers in rivers for fish migration, dredge and restore the river channel and improve fish spawning and fostering. Ecological method is to return fish and other native species. Such method is more economical and easier than any other methods, so is widely used presently. The state is increasingly subsidizes on ecological projects, the relevant organization also offer an impetus. The successful restoration projects in Sweden are the top four lakes.

By 2009, all previous public and private water supplies will be implemented in planning, including establishing water protection areas and implementing water regulations. In addition, Sweden will implement a series of projects to implement the directive in the coming years.

#### **2.9.4 Forest ecological protection**

Protection of forest resources is the basic national policy of Sweden, treasuring forest is a long – standing tradition. As early as in 1903, the Swedish Parliament set up legislations and stipulated; Who deforests, who replant new. In 1994, Sweden enacted a new forest management regulation, which established a principle of protecting ecological balance and rational developing forest resources. Based on the new rules, Swedish government continuous hold series of ecological and environmental protection training courses, and hundreds of thousands of people took part in the study and training. For protecting the diversity of forest species, Sweden established a gene bank of trees responsible for collection and preservation of genetic material of national rare species. Thanks to Swedish love of forests and strict managing forest resources, and since 1920, Swedish forest storage not only decreased because of large – scale logging, on the contrary, increased about 100 million m<sup>3</sup> every year so that the total storage capacity grew by 60%.

In protection of forest resources, Swedish is trying to improve utilization of forest products as much as possible, reduce use of timber to protect forest resources indirectly. Forestry is one of the major export industries for foreign exchange in Sweden. Because forest played an important role in the national economy, Swedish paid more attention to the protection of forest resources, gradually build up an integrated industrial chain from forest logging to pulp production, and form a resource – saving mode. Utilization of the waste paper recycling in Sweden is high up to 69%, while the average recycling rate in the other European countries is only 56%. Sweden has been put the environmental protection in paper industry in the first place, and promote environmental management. Currently, the environmental pollution including wastewater and exhaust emissions from Swedish paper mills has been reduced greatly.

A 24 – hour rainstorm in January 2005 caused destruction of forest equaling to the national volume of timber felling in southern Sweden year, particularly shocked the country. Some thought the event might affect the achievement of the national objective “sustainable forest” by 2020. At present, the state is trying to eliminate the adverse impact. It is worth mentioning that the Swedish forest protection concept is changing from relying on the traditional nature forces to the new concept of a contract basis.

#### **2.9.5 Ecological protection in trade and industry**

Export – oriented industries in the national economy play very important roles in Sweden. According to the national development strategy, Sweden thinks that the objective of sustainable development of industry and foreign trade is to maximize the overall benefits rather than maximize

trade profits, its premise is to ensure that people have a good and wholesome environment in present and future. Under the guidance of this goal, people are truly aware of the concept that development of industry and foreign trade should not be at the expense of ecological resources, nature is not an economic resources free to be developed, and has its own inherent value. In development of industry and foreign trade, every effort should be made to protect the natural, and take environmental and social development balance into account.

A number of large enterprises in Sweden consistently insist on the production of green products, green trade, and promote the concept of green consumption in international trade and economic exchanges. In 1970s, waste recycling and clean production in Sweden has been widely accepted, and are continually enriched and developed. In 1994, Sweden promulgated the "law of Producer Responsibility", in which requires producers responsible for all product recycling. Residents picked the organic waste out to reduce waste volume, meanwhile used the organic waste as their garden fertilizers. Thanks to clean production, Swedish industrial and foreign trade went forward in a sustainable way.

In pursuit of sustainable development, Swedish made choice to traditional industries, abandoned the industry which have severe negative impacts on the environment, and transformed industries which might have negative impacts to reduce energy consumption and pollution, improve the quality and competitiveness, and promote their sustainable development. Meanwhile, develop industries such as information and communications, biological engineering, medicine, space and so on, which are belong to high - tech industries with less pollution, low energy consumption and more value - added, focusing on research, development and product design, accelerating technological innovation to increase international competitiveness. According to statistics, about 80% of exports industrial products in Sweden are of high value - added. From the share of GDP, Sweden's export surplus was the highest in the world, and this is upgrading results of its industries.

## **2.10 Strengthening international cooperation especially with EU**

Environment problem is a global issue and closely linked to the destiny of every country, many important issues can be resolved only through global joint action, such as acid rain, marine environment pollution, protection of international rivers and migratory birds and so on, therefore it's essential to enhance international cooperation. Sweden has been participating actively in international cooperation, for instance, the Joint Environment Plan, the World Association of Economy Cooperation and Global Environment Foundation. Meanwhile, Sweden is more closely cooperated with countries in the Nordic and Baltic Sea on environment problems.

As early as 1972, the first United Nations General Assembly held in Sweden, promotion of international environmental cooperation has become an important feature of Sweden's foreign policy. It has three objectives: first, achieve Swedish environmental quality objectives, second is pursuit of good global environment, third is reducing poverty around the world. Protection of natural resources and environment is one of the main goals that Swedish pursuits in international cooperation policy.

Since Sweden became a member of the EU in 1995, a new opportunity has been provided to Swedish policy of the ecological environment, environmental work also underwent some major changes. In the attainment of national environmental quality objectives, Sweden government gave priority to EU's four requests and got parliament consent in 2003. These four areas are: first is the atmosphere and air pollution, including support EU play a leading role in negotiations of atmosphere. Second is sustainable consumption and production, management of chemicals, resources and waste according to EU requirements. Third is natural resources and ecology diversity, including greater concern of ecological environment according to EU Common Agricultural Policy (CAP). Fourth is marine environment, recognize it's critical for EU to carry on marine protection and preservation strategy.

Regarding international cooperation, SIDA (the Swedish International Development Cooperation Agency), plays an important role. SIDA, attached to the Swedish Foreign Ministry, develops international cooperation with other countries and regions according to requirements and

financing from Swedish Parliament and government. SIDA is a global organization, with its headquarters in Sweden, its offices distributed in more than 50 countries and regions in the world.

SIDA does its work in accordance with the general cooperation projects. In 2004, 63% of Swedish government development cooperation budget, about 12.4 billion krona is organized and implemented by SIDA.

## **2.11 Citizen participation in ecological protection is the cornerstone**

To achieve the country's sustainable development strategy, Swedish departments, provinces, local governments formulated "21st Century Agenda", developed more detailed and specific goals, planning and policy in their respective areas. In the course of local sustainable development, it's very important for the various social strata and organizations, such as local government, city authorities, companies, schools, farmers, non-governmental organizations participation. But the most important thing is to arouse the public's awareness, incorporate sustainable development into the public's thinking and actions.

## **3 Apocalypses for China**

According to the experiences of Swedish ecology rehabilitation, some apocalypses can be got for China.

### **3.1 Establishing detailed and specific national ecology environment objectives**

In China, although ecology environment construction plans have been constituted, and aims have been established, a unified, concrete, specific environment construction plan which can be comprehended and accepted easily by the public has not been made. We suggest that the Swedish experience can be used for reference, to research and establish and enact environment quality objectives, make clear the direction of ecology construction, harmonize ecology protection and construction, standardize ecology environment monitoring and appraising, and improve the ecology environment consciousness of the public.

### **3.2 Establishing and consolidating policy about ecology environment construction and protection**

The root of issues of ecology, including water and soil erosion, is the pursuing of economy disregard the cost of ecology. At the same time, the ecology protection, including water and soil conservation, involves every side of economy and society, especially that it cannot leave aside consciously participation of the farmers. So, using the Swedish experience for reference, using market measures, by the economy lever is a very effect track to motivate and inspire every aspect of the country to participate ecology protection.

At present, the ecology environment construction of China relies only on the invest of the government, and the pace of the ecology construction is slow. This status goes against mobilizing the enthusiasm of all the society to protect and develop ecology, it's not fit for socialism market economy circulating rules, and restricting the realization of national ecology strategy. Therefore, we suggest that experience of Swedish, even of the Europe, can be used for reference, using the green tax concept, gives the farmers, enterprises and industries that engage in environment rehabilitation some compensation to protect their benefits through free revenue and subsidies, makes the damagers of the ecology lost more than their benefits, improves the enthusiasm of all aspects of society and the ecology builders, embodies the harmonious and equity of the society, and drives the ecology environment construction to develop all-sided, fleetly and soundly.

### **3.3 Quickening the pace of ecology rehabilitation**

Rehabilitating the destructed ecology environment is the only choice of any country, not only



for Swedish, but also for China, which has huge pressure of population and environment.

According to the experience of Swedish, first, the ecology rehabilitation must be done early, it's better to do it before the damage is spread so as to avoid more serious aftereffect. Second, from the point of view of all the aspects of ecology, society and economy, analyzing the benefit of rehabilitation is to decide reasonable order, emphases, process and methods of rehabilitation. Third, make use of natural law as much as possible, from holding out man-made disturb, adopting ecological method to quicken the pace of rehabilitation. Forth, by using compact, assure the benefit of the ones who do the rehabilitate work. Fifth, make the duty clear, according to principle of "who damage it who pays for it", make sure who is responsible, so as to avoid that all the respond is taken by the government.

### **3.4 Intensifying environmental legislation and law enforcement**

Compared with our country existing environment protection laws and regulations, Swedish environment legislation had the characteristics of simplification, clearly, concrete, unified, coordination, illegal punishment heavy and so on, hence it was convenient for using and supervising, and the legal deterrent strength is strong. All these advantages are suggested to use for good reference when our country related laws and regulations are formulated and revised.

By comparison, laws and regulations enforcement in Sweden is better than that in our country, and things such as against law were seldom happen. The effects of law enforcement is visible, and supervision requests can be fulfilled timely.

Recommendations are that, from the institutional system, government functions, credibility management, responsibility charging, punishment and other aspects, effective measures should be taken to enhance law enforcement, and focus on maintaining the dignity of the law. Meanwhile, self-controlled system about Soil and Water Conservation should be established as soon as possible, reporting system of Soil and Water Conservation should be modified, and accordingly stipulations must be step up and specific requirements have to keep clear.

### **3.5 Promoting environmental protection technology research and development vigorously**

Based on today's world economic development trends, from sustainable development strategy point of view, the ecological and environmental protection technology, particularly high environmental technology research and development, should be taken as the state's key support field, and more specific and effective measures should be adopted to promote it vigorously. On this aspect, two points should be stressed particularly. Firstly, the state's overall coordination must be strengthened to integrate various forces to make great efforts on research. Secondly, international cooperation must be strengthened to hold foreign trends timely, and exploit international strategic market.

### **3.6 Striving to increase public awareness of the ecological environment**

On one hand, many methods such as education, training, publicizing can be used to increase the social awareness of the ecological environment. On the Other hand, soliciting and receiving public views must be paid particular attention in environment policy-making, change the outdated model of government and professional sectors "close doors to engage in planning", increase community participation, make environment decision-making more scientific and feasible.

# Proposed New Dam Turbidity Countermeasure Method Applying an Agricultural Water Use System

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**Abstract:** Rivers and water cycling structures including artificially constructed dams, storage ponds and channels linked to rivers have, over a period of many years, been firmly established in agricultural regions. Based on the investigation of Dam C in Japan, new approach against dam turbidity problem is proposed in this paper. This method utilizes the above – mentioned water cycling structures as agricultural water use systems and details of it are summarized below. ① To the irrigation dam reservoir where stratification is formed then disrupted repeatedly as part of a large repetitious annual cycle, selective discharge methods is effective. ② Turbid water taken selectively from the dam can be stored to provide the pond with the functions of a sediment check dam or settling basin. ③ During a non – irrigation period, paddy fields can be used to reduce turbidity by actively supplying them with turbid water to treat them as settlement ponds.

Using an existing agricultural water use system that forms the water cycle of a drainage basin is a low cost and rational method that conforms with the concept of harmony with nature by not requiring the construction of new facilities and investment of additional energy.

**Key words:** irrigation dam, turbidity problem, storage pond, paddy field, agricultural water use

## 1 Introduction

Japanese agriculture has been centered on paddy field rice growing since ancient times. This research project focused on fields that were developed along rivers and their tributaries located in a classical paddy field zone in Japan. The study begins by considering the relationships of rivers with paddy fields.

In paddy fields zones, water needed for cultivation must be supplied, and because it is obtained as either river water or ground water, this water supply is closely related to rivers and the topography formed by rivers. It is also assumed that the form of paddy fields is closely related to the shape and ranking of rivers.

For example, flat ground formed on low plains in the downstream regions of major rivers used to be widely used as paddy fields, forming grain production zones. This is a benefit provided through the hard work of our ancestors; building weirs to accumulate water on alluvial fans formed by the river over periods of many centuries, then distributing the water that has been accumulated in this way to every corner of the alluvial fan by excavating artificial channels. Flood control works that fix rivers in permanent courses have transformed old river courses into irrigation use supply channels and drainage channels.

And in Japan, unique paddy field scenery has also been created in valleys and on tributaries from the middle to the upstream parts of rivers. There is a type of paddy field zone called yachida (valley bottom fields): paddy fields often developed with water obtained from storage ponds built to collect water leached from forests or plateaus or groundwater. In mountainous districts where landslide topography has formed, unique scenery has been created by developing terraced paddy field zones called tanada (= shelf fields = terraced fields) using ground water sources characteristic of landslide ground.

On land where there was no flowing river water, and where it was originally impossible to create paddy fields without a water source, long irrigation channels linking drainage basins have been constructed to develop new paddy field zones. Stories of illustrious people who invested their assets and employed all available technologies to excavate irrigation channels to benefit future generations have been handed down throughout Japan.

In these ways, rivers and water cycling structures including artificially constructed storage ponds, irrigation water supply channels, and drainage channels linked to rivers, plus ground water that supplements these structures have, over a period of many years, been firmly established in regions. This report refers to these water cycling structures as agricultural water use systems. It is these that have formed the paddy field scenery unique to each region.

This research proposes a brand new approach to the resolution of turbidity problems that occur in dams that now supply water to paddy field regions. The new concept is limited to maximizing the use of the agricultural water use systems that have already been established over a long period in each region. It is clear that it is not a countermeasure method suited to a river carrying a massive quantity of sediment, the Yellow River for example.

However, the following new concept of a dam turbidity countermeasure method is introduced assuming it can contribute to the resolution of dam sedimentation problems in some way to show the rationality of using systems that are potentially available in a region.

## 2 Agricultural water use projects in Japan

In this chapter, I will describe agricultural water use projects in modern Japan. To study an agricultural water use system, it is presumed to be important to clarify just how to implement the project.

A water use project intended to develop paddy fields differs from a public works project such as a flood control project. Paddy field development is, in principle, undertaken with the cost borne by the beneficiaries based on an application by a farmers association that is an alliance of farming households. But in fact, in light of the public character of such a project, administrative bodies in the region generally reduce part of the financial burden on the farming households.

As a consequence of the above project characteristics, a paddy field irrigation project in Japan is undertaken mainly to supply additional water by improving the water sources, to expand and strengthen the existing water use system, and to operate it more efficiently and more effectively. In other words, the principle of an agricultural water use project in Japan is supplementary irrigation.

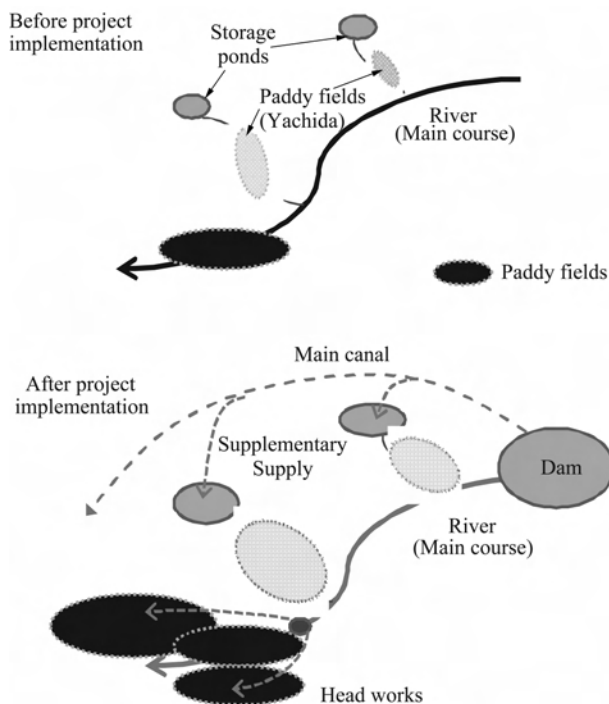
There are cases where, as a national policy, new agricultural land is developed and occupied by its developers by constructing new irrigation water supply channels at locations where they had never previously existed. For example, this happened during the period of high speed land development following World War II. Such projects are of course not called supplementary irrigation.

Fig. 1 is a diagram showing an example of a typical improvement case based on the implementation of a project. The improvement of agricultural land consisting mainly of paddy fields is undertaken by constructing new infrastructures such as dams, head works, storage ponds, and other water source facilities along with water transport channels such as water supply channels and water drainage channels. In other words, by reconstructing and upgrading the functions of the agricultural water use system.

## 3 Dam turbidity problems—Case of Dam C

### 3.1 Outline of the district

The district that was selected for this research was dependant on an existing storage pond and on groundwater for paddy field water prior to the project. A water supply dam was constructed at the upper end of the drainage basin by a prefectural water supply improvement project authorized in



**Fig. 1 Construction of a water use system by a project (Supplementary Irrigation)**

1958 in response to a request by the region. The water newly produced by this dam was supplied to the existing storage pond through a main irrigation channel, stabilizing and strengthening the region's water sources. The stabilized water source infrastructure and the construction of channels expanded paddy fields and improved water use in the region.

The following is an outline of Dam C constructed by this project.

Location: Kanto region, Japan

Completed: 1967

Catchment area: 14.8 km<sup>2</sup>

Total water storage capacity: 2.113 million m<sup>3</sup>

Design flood runoff flow rate: 308 m<sup>3</sup>/s

Dam type: rock fill dam

Dam height: 36.7 m

Dam length: 110 m

Spillway: side channel type side ditch spillway

Intake method: floating surface intake method

A restoration project intended to deal with deterioration over time of the intake and discharge systems and to improve their functions is now in progress.

### 3.2 Problem of turbidity at Dam C

The turbidity prolongation phenomena appeared about 30 years ago in Japan; mainly at electric power production and flood control dams, followed by the establishment of a variety of countermeasure methods. The actual state of problems with turbidity at agricultural water supply

dams used to be unclear, because of the construction period and slow advance of the phenomena. But in recent years, the facts have gradually been clarified (Taruya, 2005).

It is reported that the problem of turbidity at Dam C appeared about 1990. Specifically, locals pointed out the following phenomena that are characteristics of the problem of prolongation of turbidity.

The dam reservoir surface remained turbid no matter when it was inspected.

Even after turbidity had abated in the upstream river after the end of the flood runoff, turbidity in the dam reservoir and downstream from the dam did not abate for a certain period.

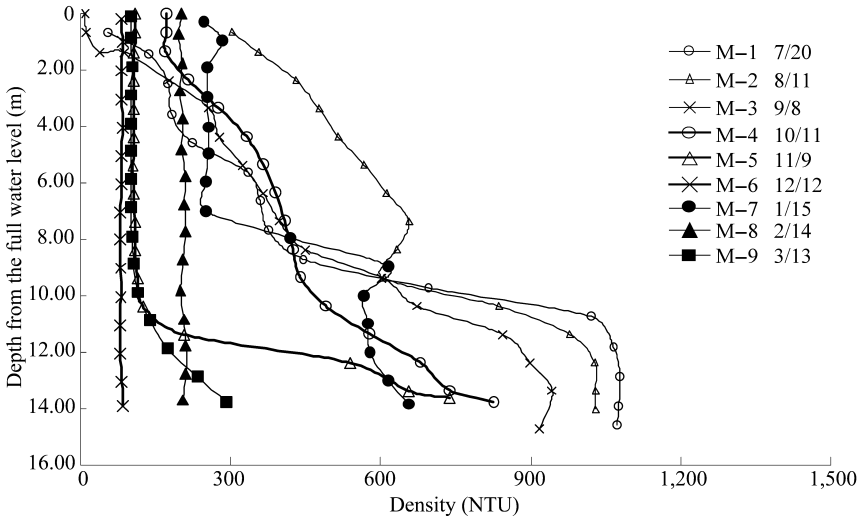
In the drainage basin of Dam C, the geology is marked by a series of rising and falling serpentine and basaltic layers along a fault in a Neogene Period mudstone layer, forming a classical landslide zone, that has long been a region producing large quantities of sediment. The sediment flowing into the reservoir includes clay minerals and plagioclase that originated in mudstone and shale. An analysis of bottom mud sampled from the reservoir bed was found to have grain size ranging from  $10^{-3}$  to  $10^{-2}$  mm.

### 3.3 Turbidity survey methods and survey results

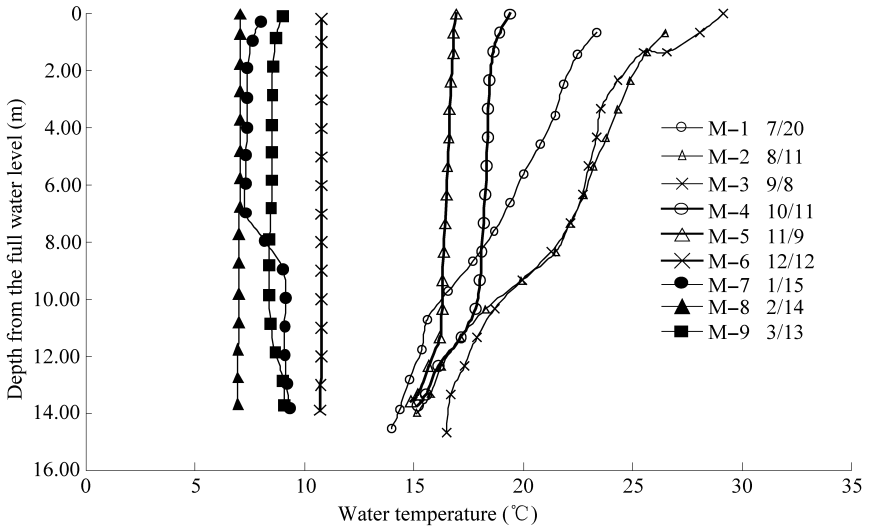
In response to a request by the prefecture, the National Institute for Rural Engineering (NIRE) surveyed the state of turbidity at Dam C and analyzed the data obtained from July 2006 until March 2007.

#### 3.3.1 Survey of turbidity and water temperature distribution in the reservoir

To find out how the degree of turbidity inside the reservoir fluctuates spatially and seasonally, NIRE personnel observed the vertical distribution from the reservoir surface at intervals of 1m over the entire lake once a month (periodic observations). The items observed were, in addition to turbidity, also water temperature, electrical conductivity, pH, DO, etc. Parts of the results of the survey of turbidity and water temperature are presented in Figs. 2 and 3 respectively. The results do not show any substantial differences in the distribution of the observed values at different observation points throughout the dam reservoir.



**Fig. 2 Density distribution results in the Dam C reservoir (periodic observations M-1 ~ M-9)**



**Fig. 3** Water temperature distribution results in the dam C reservoir (periodic observations M-1 ~ M-9)

### 3.3.2 River turbidity survey

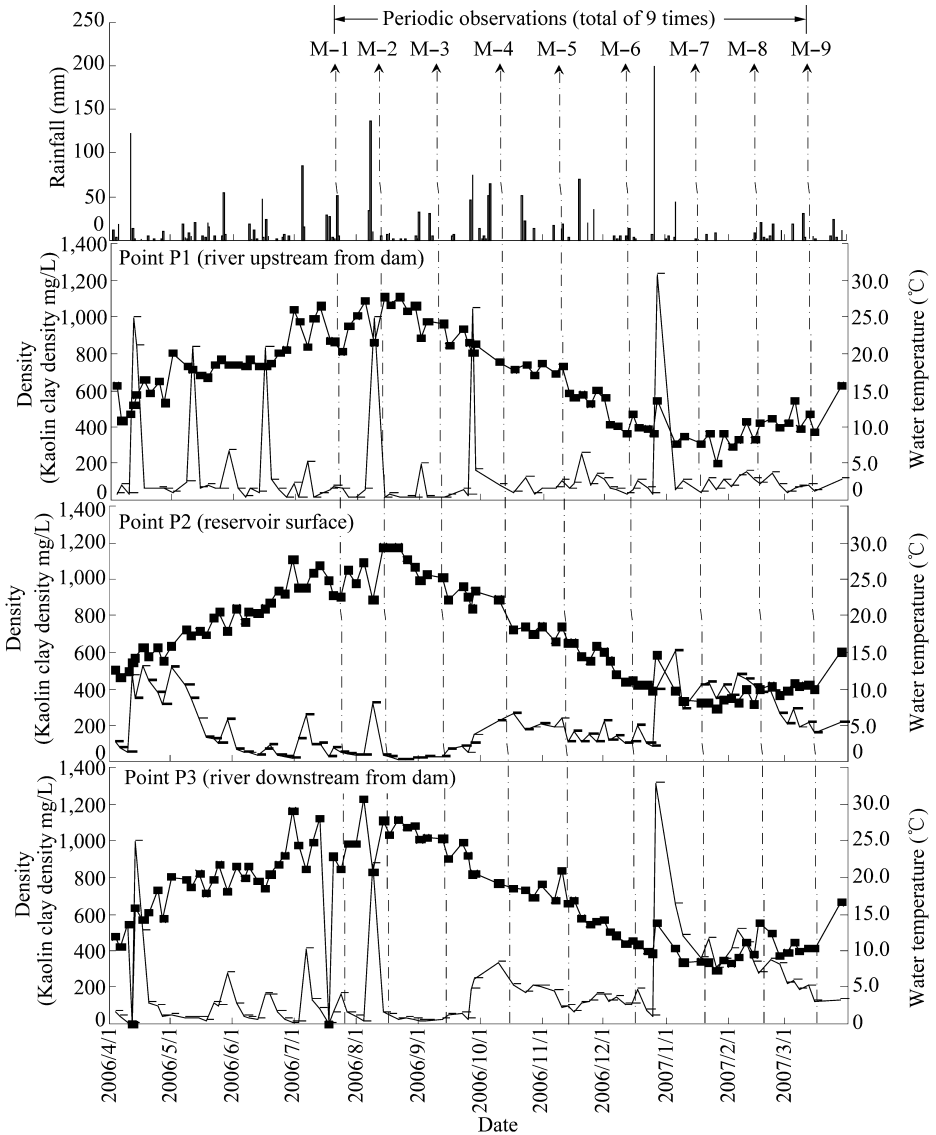
Until then, the prefecture had continuously observed turbidity and water temperature data once every three days on the reservoir surface and at points along the river upstream and downstream from the reservoir. Fig. 4 presents observation data obtained at three points—point P1 on the river upstream from the dam, point P2 on the reservoir surface, and point P3 along the river downstream from the dam—and observation data for approximately one year accompanied by daily rainfall (mm/d) data.

### 3.4 Consideration of the survey results

Fig. 2 and Fig. 3 reveal the following facts. Water temperature distribution results show thermal stratification in the summer and the disruption of this stratification and mixing of the strata in the fall and winter. This is assumed to be a product of the so-called “Major autumn cycle”, that is a phenomenon characteristic of a stratified reservoir. The turbidity distribution also reveals that in response to the thermal stratification, density stratification formed and was disrupted. It is confirmed that the turbidity of the bottom stratum was relatively high in the stratification period during abnormal rainfall in January.

The high concentration of the bottom stratum was more stable during this period than during other seasons. It is not clear what kind of mechanism originally caused the high turbidity of the bottom stratum, but it is possible that it is a highly concentrated density current flowing into the bottom stratum or the stirring up of the bottom material by this current. In August, there was a temporary increase of the turbidity in the middle stratum (4.0 m to 10.0 m) where inter flow in density current phenomenon was observed.

Next we consider Fig. 4. Turbidity at point P1 that is the location upstream from the dam occurs in response to rainfall. But, at point P2 in the reservoir and at point P3 downstream from the dam, the relationship of the rainfall with turbidity is not as clear as it is at point P1, and seasonal differences are found. During the period from M-1 to M-3 when stratification formed in the reservoir, the locations and the scale of the turbidity peak at points P1 and P3 confirm closely, but during the period from M-3 to M-9, there is little correspondence excluding that caused by the



**Fig. 4** Comparison of changes of turbidity and water temperature at, upstream from, and downstream from dam c reservoir

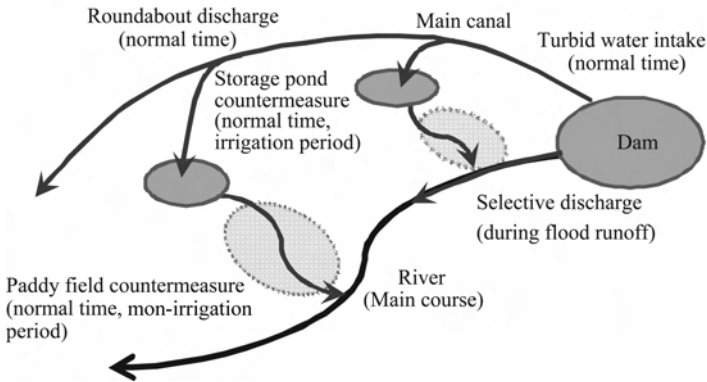
abnormal rainfall in January.

After M-3 when the stratification was disrupted, mixing the strata, excluding the period of abnormal rainfall in January, at points P2 and P3, high turbidity between 200 to 400 ppm (density equivalent to kaolin clay) continued regardless of the turbidity fluctuation at point P1. This suggests the so-called turbidity prolongation phenomenon.

#### 4 Turbidity countermeasure method applying an agricultural water use system

This chapter introduces the concept of the new turbidity countermeasure method that applies an agricultural water use system. This concept is now being studied in this district since it was proposed as a turbidity countermeasure for Dam C as a typical irrigation dam. The chapter also describes guidelines to planning how to upgrade existing facilities to implement the new method.

The basic concept of the countermeasure method introduced by this study is to make the maximum possible use of the functions including latent functions of each unit water storage facility at each drainage basin rank—dams, storage ponds, paddy fields—that are part of an agricultural water use system, and in this way strengthen their effectiveness as an overall system. Assuming that it is appropriate to show turbidity transport channels and this method in order to reveal the overall image of this countermeasure method, the form in Fig. 1 is borrowed and reorganized as shown in Fig. 5.



**Fig. 5 Schematic figure of turbidity countermeasure method applying an agricultural water use system**

Fig. 5 shows the process from the discharge of turbid water from the dam through the storage pond to the paddy field as a process of successive movement to the lower drainage basin ranks. It is important that the times that turbid water is transported are distinguished between flood periods and normal periods and between irrigation periods and non-irrigation periods, and these times are shown on the figure matched to these key words.

The following are detailed explanations of the countermeasure method at each unit storage facility rank.

##### 4.1 Countermeasure at a dam

As has already been discussed, in the reservoir of Dam C, stratification is formed then disrupted repeatedly as part of a large repetitious annual cycle. At a flood control dam or electric power dam, highly concentrated turbid water is discharged selectively to the river during the flood runoff period (selective discharge methods). In this district, it is appropriate to adopt this method.

##### 4.2 Countermeasure by a storage pond

The functions of a storage pond in an agricultural water use system are to store water from the drainage basin and to temporarily store water taken from the dam, then to supply it when the paddy fields require water. To use it effectively to implement a turbidity countermeasure, turbid water taken selectively from the dam is stored to provide the pond with the functions of a sediment check dam or settling basin formerly constructed upstream on the river as turbidity countermeasures. When



it is used as a sediment check dam, it is possible to fix the bottom mud to prevent it from being suspended again and to increase the efficiency of excavation work by drying the pond during the non – irrigation period.

This is not only done by encouraging gravity suspension as a settling basin function; the possibility of applying chemical treatment to accelerate the settlement speed should also be studied.

### 4.3 Countermeasure at paddy fields

During a non – irrigation period, the operation of paddy fields varies according to the form of farm operation, but basically, they are left untended. Paddy fields are used to reduce turbidity by actively supplying them with turbid water to treat them as settlement ponds during the non – irrigation period. And the aim is to purify drainage water flowing downstream into drainage channels by taking advantage of the settlement pond function of the paddy fields. Subsurface pipe drains are usually constructed under paddy fields, and the combined purification effects of paddy field seepage water and the filtering effects of the subsurface pipe drains are counted on.

Assuming that the effectiveness of this method varies according to the way each paddy field is cultivated, a verification test using a local paddy field was done in order to verify and quantitatively evaluate its effectiveness as a countermeasure method. The next section presents the method used for the field verification test done from January to March 2007 and the results of the test.

### 4.4 Field verification testing of reduction of turbid water by a paddy field

With the advance approval of the landowner, one paddy field lot (about 1,800 m<sup>2</sup>) was borrowed and supplied with turbid water to perform this test from January to March that is the non – irrigation period. As water was supplied, the flow rate and turbidity at three points—point where water was supplied to the paddy field and the points where water was drained from the paddy field (surface drainage point and culvert drainage point)—were measured automatically at measurement intervals of 5 minutes. The turbid water supplied to the paddy field had been taken in by the dam and transported to the paddy field through a storage pond, but it varied according to the way the turbid water was taken in. From February 15 to March 1, the turbid water with the highest degree of turbidity was supplied to the paddy field.

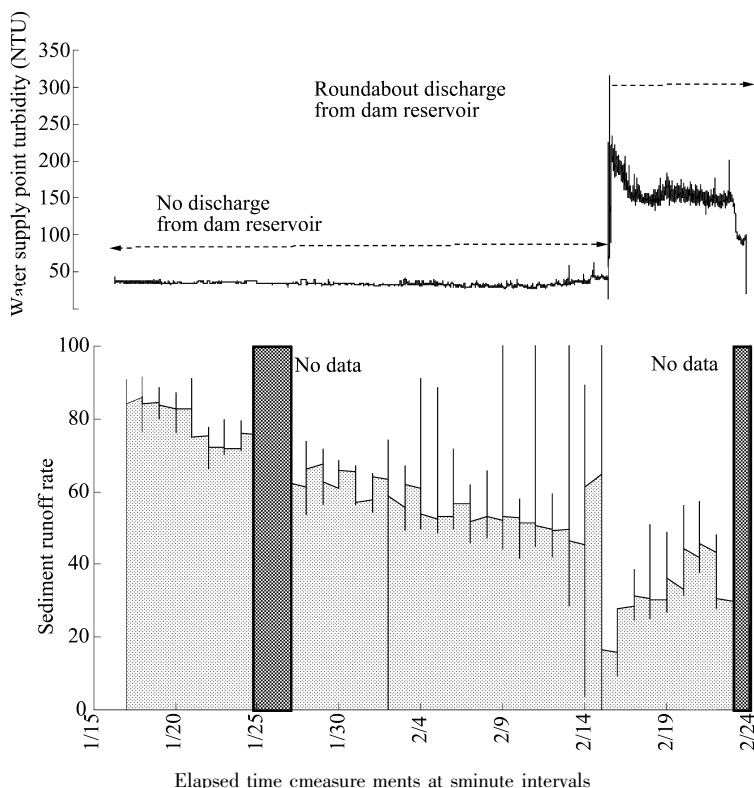
The turbidity data were all converted to sediment concentration, and ultimately, converted to sediment quantity based on the product of the flow rate. And the percentage of the sediment that flowed into the paddy field that was run off was organized as the runoff sediment rate as values at five minute intervals.

Fig. 6 represents the fluctuation over time of the runoff sediment rate. These results reveal that during the period following February 15 when highly concentrated turbid water flowed into the paddy field, it was possible to hold the sediment runoff rate to approximately 30% to 40%.

### 4.5 Functions that must be added to water use facilities

It is clear that in order to realize the above countermeasure method, it is not enough to simply update the existing facility functions. The essential major facility functions that are improved, strengthened, or added to the existing facilities of Dam C are organized below.

The existing discharge system consisted only of the bottom stratum discharge gate (now malfunctioning) and the gateless side channel type spillway, so in order to apply the above method, it is necessary to reconstruct existing facilities to provide them with selective discharge functions. The quantity discharged by the dam's selective discharge method must be constantly maintained within the amount the reservoir water level discharges over its weir crest on the existing side channel spillway. Or it is necessary to devise a way to replace part of the overflow from the dam spillway with the discharge flow rate produced by the new method (selective discharge method). As an example, it is appropriate to install discharge facilities that permit automatic switching between



**Fig. 6** Fluctuation of the sediment runoff rate in the test to verify turbidity reduction by a paddy field

running and shut down according to the reservoir water level.

As the previous dam intake system, a surface stratum intake method was adopted to take in warm water. But, in order that storage pond or paddy field countermeasures be undertaken effectively, it is necessary to add functions to efficiently take in turbid water at the dam. Therefore, it is necessary to revise the existing dam intake facility to a selective intake method for all strata.

In a case where a storage pond is used as a settlement basin or as a sediment check dam, as necessary, a plant to treat bottom sediment and a connection road necessary for periodic sediment excavation must be constructed, a yard to dump excavated sediment ensured, and a reuse method determined.

## 5 Conclusions

An outline of a countermeasure method of reducing turbid water by applying an agricultural water use system to resolve dam turbidity problems has been explained. As a major premise for this discussion, the process of establishing an agricultural water use system focused on paddy fields in Japan and the process of strengthening these by an improvement project was reviewed. Based on the survey of Dam C, dams, storage ponds, and paddy fields that are the constituent parts of an agricultural water use system are treated as facilities typical of each drainage basin rank to discuss the possibility of reducing turbid water by taking advantage of the functions that each of these facilities already provides.

Using an existing agricultural water use system that forms the water cycle of a drainage basin is

a low cost and rational method that conforms with the concept of harmony with nature by not requiring the construction of new facilities and investment of additional energy. At this time, it is nothing more than a conceptual countermeasure method, but in the future, a series of studies must be performed to clarify the quantitative effectiveness of the countermeasure method.

To implement the countermeasure method, it is necessary to provide water use facilities that can meet the demand for new functions, so we intend to continue to carry out the necessary technical studies of methods of designing and of maintaining such facilities.

And in order that the countermeasure method introduced by this report is effectively introduced in the field, its effectiveness must be communicated widely among farmers. It is important to simultaneously create procedures to correctly receive administrative support to increase the effectiveness of the new countermeasure method that is created through cooperation among farming households.

Therefore, it is necessary to not only link administrative bodies and farmers associations, but also research organizations, in order to explain its effectiveness to, and gain the understanding of, all concerned parties.

### **Acknowledgement**

The authors are deeply grateful to those employees of the prefectural administration center who provided their kindly assistance during our field survey.

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# Eco – environmental Water Requirements Based on Support Vector Machine for the Seashore Region in Yellow River Estuary\*

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**Abstract:** In view of the diversity and conformity of biology in the Yellow River estuary, and considered the influence of phytoplankton, sediment concentration, configuration of estuary, climate, and the change of season to the eco – environmental water requirements, a support vector machine (SVM) model using its powerful non – linear mapping ability to deal with input variables including concentration of chlorophyll, water level, runoff, sandiness and Sea Surface Temperature was set up, the quantificational study of the least eco – environment water requirements of seashore region in representative years for Yellow River estuary is realized, and the forecast results are compared with the BPNN output data.

**Key words:** eco – environmental water requirements, support vector machine, NN, seashore region, Yellow River Estuary

Estuary is an ideal habitat as alternant region between two earthly water area ecological systems for many aquicolous and swampy biology. The utilizing and developing of water resources in Yellow River estuary mainly considered the needs of agriculture, industry and daily life for long time, the overmuch exploitation engrossed the water resource ecological space, and the water used to maintain the balance of environment has not been regarded enough. Irrational exploitation and utilization of water resources destroyed the frame and function of ecosystem; Draining the rubbish and exhaust heat into the estuary directly or indirectly had made the environment become more fragile and the function of estuary more degenerate, so that the persistent development for Yellow River estuary area was restricted.

Based on the foregone hydrological research results and combined the technology of support vector mechanics (SVM), taking the concentration of chlorophyll, water level, runoff, sediment and Sea Surface Temperature as input variables, this paper will set up a non – linear model for predicting eco – environmental water requirements, the main aim is to provide basal data for regulating water and sediment as well as healthy development of eco – environment in Yellow River estuary.

## 1 Contrast of several non – linear methods for eco – environmental water requirement research

At present, there is not any accepted definition for eco – environmental water requirements because of the difference between the spatial – temporal scale and connotation of environmental water requirements. From broad sense to say, the eco – environmental water requirements can be considered as the water maintaining the global ecosystem balance included water to heat, water to sediment, water to salt and so on. From narrow sense to say, the eco – environmental water requirement is equal to the gross dissipative water for protecting environment from deteriorating. It includes the water for protecting and resuming the natural vegetation, environment of inland river, water and soil conservation, forests and grass construction out of protective area, maintaining the balance between water and sediment as well as water for basal runoff in swamp and water area, groundwater return, etc.

The non – linear methods used to predict eco – environmental water requirements include G

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(1,1) model based on gray theory, fuzzy mathematics theory and NN technology. The gray theory is more fitted for small samples and indigent information systems; Fuzzy mathematics is a sort of mathematical method for manifesting and processing fuzzy information, it is of much superiority, but it also needs building mathematical model to solve any problems. Whereas the influencing factors of eco – environmental water requirements are numerous, it is very difficult to found mathematical model used to understand fully the mechanism of eco – environment requirement water.

So far, applied the NN and SVM to learn and predict the eco – environment water requirement has become feasible. The analysis and modeling results shown that NN is better performance and efficiency than any other tradition methods, but it still exists some limitations; the structure of network needs initialization or searching in the course of training, the number of hidden node in network is hard to confirm, there aren't academic guidance about how to adjust the weight of network and how to initialize the network, the course of training is inclined to minimum pole, the convergent speed is slower relative to other non – linear methods and the learning tends to be excessive. The performance of this method might be not perfect due to they are on the basis of conventional statistics. The NN adopts the rule of empirical riskminimization which minimizes the samplings in the course of training so that it inevitably simulates excessively and the extending ability of model is limited, besides it will be exact only when the number of the samplings closing to infinite. In fact, the number of the samplings cannot be infinitude; it indeed is quite finite at time.

More over, the SVM is based on the statistical learning theory which pursues least actual risk by splitting the difference of empirical risk and credible range what just is the structural riskminimization (SRM). Essentially it aims to get the best generalization ability by considering it and the complexity of machine (accuracy of learning about the given samplings) synchronously. Compared with ANN, the SVM will not run into minimal pole and has better generalization ability, so that its performance is more ascendant than ANN. At present, the SVM has been widely used in many fields such as text identification, sound and face recognition, burthen, stockmarket, and underground water table prediction.

## 2 The principle of SVM

### 2.1 The best hyperplane

Given a set of training data points  $X_i$  whose dimension is  $d$ . It is separated by the hyperplane defined by the following equation:

$$\omega \cdot x + b = 0 \quad (1)$$

The basic concept of the SVM is searching for a hyperplane that has maximum margin. Such as two – dimension questions, it namely is finding the superior separation line as the Fig. 1 shown. The solid and hollow points represent two kinds of sampling respectively,  $H$  label is separation line, then  $H_1$  and  $H_2$  are beelines crossing the two samplings which are closest and parallel to the separation hyperplane respectively, the distance between them is defined as separation margin. The superior separation line can separate the samples into two types and maximize the separation margin. Once generalized to high – dimensional feature spaces, the superior separation line turns into separation hyperplane. Samples of training on the line labeled as  $H_1$  and  $H_2$  are named as Support Vector. Bigger separation margin means that the separation machine has better generalization ability.

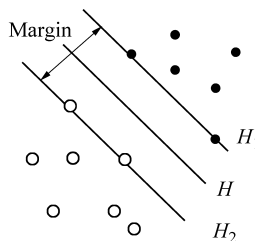


Fig. 1 Superior separation line under samples being linear separable Condition

## 2.2 Linear separable problem

Supposing the function of separation line is defined as formula (1). Generally we can assume the vector in the training test contenting the following inequation: when  $y_i = +1$ ,  $\omega \cdot x + b \geq 1$ ; when  $y_i = -1$ ,  $\omega \cdot x + b \leq -1$ . Merged the both we can get the following inequation:

$$y_i(\omega \cdot x_i + b) \geq 1 \quad (2)$$

with the definition of superior separation hyperplane, the separation margin is defined as follows:

$$d(\omega, b) = \min_{x_i^d y_i = 1} \frac{\omega \cdot x + b}{\|\omega\|} = \max_{x_i^d y_i = -1} \frac{\omega \cdot x + b}{\|\omega\|} = \frac{2}{\|x\|} \quad (3)$$

it is obvious that maximal separation margin equals to minimizing the  $\|\omega\|$ . Hence the question can be transformed into minimizing the  $\|\omega\|^2/2$  subjected to the inequation (2). By means of the Lagrange Multipliers, the problem can be expressed as follows:

$$\Phi(\alpha) = \sum_i \alpha_i - \frac{1}{2} \sum_{i,j=1}^k \alpha_i \alpha_j y_i y_j (x_i \cdot x_j) \quad (4)$$

subject to  $\alpha_i \geq 0$ ,  $\sum \alpha_i y_i = 0$  and has the one and only answer. It is a dual optimization problem satisfying inequation constraints. Thus the samples corresponding to nonzero value  $\alpha_i$  are Support Vectors. The superior separation function is:

$$f(x) = \text{sgn}(\omega \cdot x + b) = \text{sgn}\left(\sum_{i=1}^{N_s} \alpha_i y_i x_i \cdot x + b\right) \quad (5)$$

where,  $N_s$  is the number of Support Vectors,  $b$  is classification threshold.

## 2.3 Linear unseparable problem

If the training samples are linear and impartible, by adding a slack variables  $\xi_i \geq 0$  to the formula, could get  $y_i(\omega \cdot x_i + b) \geq 1 - \xi_i$ . Obviously, when classification goes away there is  $\xi_i \geq 1$ . Thus  $\sum \xi_i$  is a upper limit of error number. Considering both minimizing the wrong classification samples and maximizing the separation margin, the target function is defined as follows:

$$\Phi(\omega, b) = \frac{1}{2} \omega \cdot \omega + C \sum_{i=1}^k \xi_i \quad (6)$$

where,  $C$  is a constant larger than zero. It controls the disciplinal degree and is named disciplinal gene. On the basis of Lagrange Multipliers the problem can be transformed to minimizing the formula (4) under the constraints condition  $0 \leq \alpha_i \leq C$  and  $\sum \alpha_i y_i = 0$ .

## 2.4 The kernels function of SVM

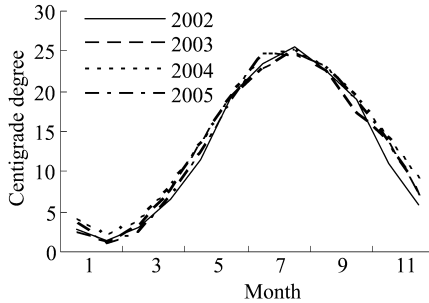
Kernel function is described as follows; supposing  $x$  is the input vector and  $Z$  is the feature space vector by transform, then defines  $Z = \Phi(X)$ , we can get the Kernel function  $K(X, Y) = \Phi(X) \cdot \Phi(Y)$ . According to functional analysis theory it can correspond to the inner product in transforming space. Some kernel functions in common use are polynomial kernel  $K(X_i, X) = (X_i X + 1)^d$ ; radial - basis function (RBF) kernel  $K(X_i, X) = \exp(-\|X - X_i\|^2 / \sigma^2)$  and two - layers nerve kernel  $K(X_i, X) = \tanh(k X_i X + \theta)$ .

## 3 An example of predicting eco - environmental water requirements at the seashore region of Yellow River estuary based on SVM

### 3.1 Data selection

Hydrological and sediment data are introduced from Lijin observation station of Yellow River

included month by month from the year of 2000 to 2003. Remote sensing data come from MODIS and SWIFS of NASA, taking sea surface temperature during 2002/01 ~ 2005/12 and concentration of chlorophyll during 2000/01 ~ 2003/12, which ranged from east longitude 119°06' to 119°12' and north latitude 37°36' to 37°48' respectively. There is a lack of sea surface temperature data between 2000/01 ~ 2001/12. Therefore we used the data between 2002/01 ~ 2005/12 to substitute them in view of the sea surface temperature changes tiny from year to year. Sea surface temperature of Yellow River estuary is shown as Fig. 2.



**Fig. 2** Sea surface temperature in the Yellow River estuary

### 3.2 Gray correlative degrees analysis between runoff and the other parameters

Chlorophyll concentration, Sea Surface Temperature, water level, sediment concentration are regarded as importance factors to eco – environment water requirements. To research their relativity quantification ally, a program used IDL6.0 to analyze gray correlative degrees by considering the runoff as system factor and others as system character was written; the analysis results show as Table 1.

**Table 1** Grey correlative degrees between Yellow River estuary runoff and other parameters

Grey correlative degrees	Water level	Sediment concentration	Chlorophyll	Sea surface temperature	Sequence of correlative degrees
Absolute	0.501,5	0.896,6	0.500,9	0.612,8	B > D > A > C
Relative	0.504,9	0.822,8	0.504,0	0.600,7	B > D > A >
Csynthetical	0.503,2	0.859,7	0.502,5	0.606,7	B > D > A > C

The table 1 shown that the absolute, relative and synthetical correlative degrees are all bigger than 0.5, it indicates that they have correlativity with runoff. And all taxis of the three correlative degrees are; sediment concentration > sea surface temperature > water level > chlorophyll. It makes clear that whether in absolute, relative or synthetical consideration, the most important influencing factor to runoff is sediment concentration, next is Sea Surface Temperature and water level as well as phytoplankton.

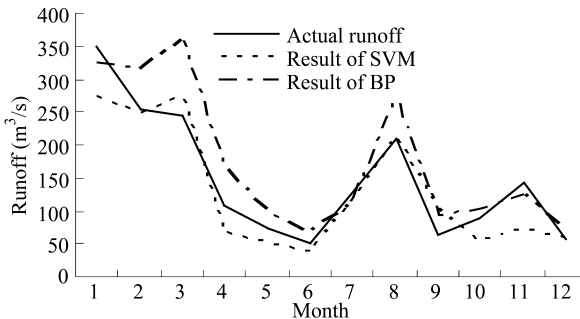
### 3.3 Method to establish the model

Based on gray association analysis, to research and predict eco – environment water requirements will become feasible. It is used a sample and efficient free software—LIBSVM that had been developed and designed by associate professor Lin Zhi – ren for creating SVM model. C – SVM arithmetic is used in this paper, namely imported a positive slack variables to split the difference between the proportion of wrong classed swatch and the complexity of arithmetic. Radial – basis

function (RBF) is regarded as a kernel function, and cross validate method is used to choose the prime parameter, then the whole swatch is trained to get the SVM model, then the testing and predicting results will be obtained by it.

### 3.4 Model construction and data forecasting

Used the data of mensal runoff, chlorophyll concentration, water level, sediment concentration and Sea Surface Temperature from 2000 to 2003 as parameter, and divided them into four groups. The former three ones are used to train model while the last one is used to test the training effect. Because of the strict inputting format of LIBSVM, the data document must be transformed and zoomed to the format of which can be used in LIBSVM before using them to calculate. The functions provided by LIBSVM are all in DOS mode. This paper mainly used SVMTRAIN and SVM PREDICT to train and predict the samples. Fig. 3 shows the forecast results in 2001.



**Fig. 3 Runoff results by SVM and BPNN methods in 2001**

By calculating, the average relative error between natural runoff and forecast results in SVM and BP method is 20.6% and 26.7% respectively. The relative error to be too large is because the data were affected by regulating water and sediment concentration, but in the same case, the applicability and precision of SVM is better than BPNN.

Generally, the chlorophyll concentration changes from 5 to 15  $\text{mg}/\text{m}^3$  just like the fact, the other vectors take the yearly average value, and used SVM emulator to calculate eco - environment water requirements. The curves in Fig. 4 show the typical trend line. If sediment concentration vector changed from 0, 5, 7, 9, 11, 15 to 20  $\text{kg}/\text{m}^3$  respectively, and seven curves can be obtained. It is obvious that the eco - environment water requirements reach to least value when sediment concentration vector was zero  $\text{kg}/\text{m}^3$ . Certainly it doesn't accord with the fact of Yellow River estuary. Therefore, the results predicted by average sediment concentration in unit time are taken as the least eco - environment water requirements.

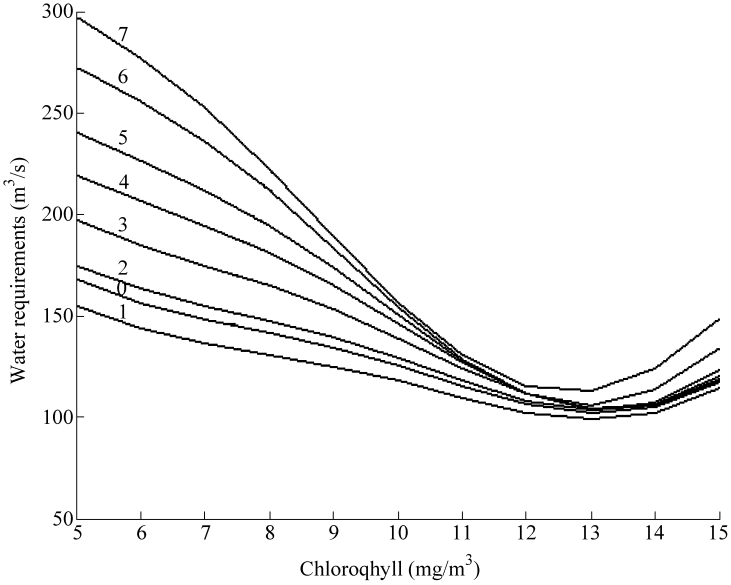
Fig. 4 shows that the water requirements has a minimum when chlorophyll going up, and the minimum can be seen as the least eco - environment water requirements. So, supposing chlorophyll changing from 5 to 15  $\text{mg}/\text{m}^3$ , and the other vectors taking mensal data of 2001, then input them into SVM and BPNN emulator, the mensal least eco - environment water requirement is obtained, the Table 2 shown predicting results.

### 3.5 Analysis of forecast results

To the supervisors, the water is superfluous or lack and how to distribute the water to fulfill the eco - environment requirements for the balance of environment need to pay much more attention. Thereout compared the least eco - environment water requirements with the natural runoff, the eco - environment water will be ample if the natural runoff is more, otherwise, the part of lacking will be the eco - environment water scarcity. The Table 2 shown that the difference between the two forecast



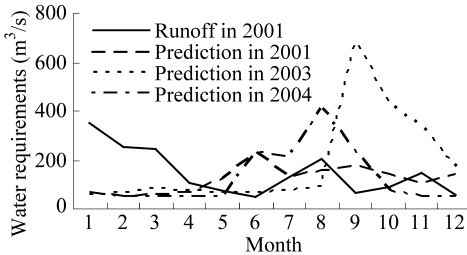
results are tiny, so the paper takes the average value as the least eco – environment water requirements. The comparison between the least eco – environment water requirements and natural runoff in 2001 is shown as Fig. 5.



**Fig. 4 Trend lines of water requirements with chlorophyll**

**Table 2 The least eco – environment water requirements in 2001 Unit: m<sup>3</sup>/s**

Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Natural runoff	349	255	243	109	73.7	52.3	128	208	65	89	144	57.7
BPNN method	70.2	52.5	60.7	65.6	131.2	218.9	135.3	153.2	170.1	146.6	99.2	128.6
SVM method	67.7	43.8	58.5	67.7	115	235.3	130	151.7	177	131	103	142.2



**Fig. 5 The comparison between the least eco – environmental water requirements and factual runoff in 2001**

Tscarcity months include May, June, September, October and December. There into the data of

June is the largest which is about 4.53 hundred millions  $m^3$  and the water of July is the nearest to the least eco – environmental water requirements. The water of other months in 2001 could reach to the least eco – environment water requirements. The average discharge in 2001 is  $118.96 m^3/s$ , the total volume is 37.52 hundred million  $m^3$ , about 23.12 ~ 28.17 hundred millions  $m^3$  less than Shen Zhenyao's 60.64 ~ 65.69 hundred millions  $m^3$  per year. The difference is mainly because the estuary terrestrial eco – environment water requirement was ignored.

The least eco – environment water requirements including actual sediment concentration in 2003 and 2004 have been laid out in document and plotted in Fig. 5. In where that the least eco – environment water requirements in 2003 and 2004 are more than the counterpoint of 2001, it is proved that the data did not affect by regulation water and sediment in 2001 is much more representational.

#### 4 Conclusions

SVM is a machine study method based on statistical research. Its merits are precision, high – speed, adaptation, unlimited by the input dimension, avoiding local minimum which can't be get over in NN method, better universality and efficiency than ANN. this paper attempts to study and predict eco – environment water requirements used SVM, and combined NN method to provide quantificational forecasting results for Yellow River estuary, the calculating results are very valuable in evaluating and programming the freshwater supply in Yellow River estuary.

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# Fuzzy Ideal Points Method in Project Construction Sequence of the Downstream of Yellow River

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**Abstract:** Based on the project construction and investment feature of the Downstream of Yellow River, the structures were divided into flood control dike, water diversion, irrigation and water saving, soil conservation and ecological projects, river mouth management and development and water resources information. Using fuzzy and decision making analysis theory and project planning investigation data, the different project weights were calculated and fuzzy ideal point model was set up. According to administrative region, the total area of the downstream of the Yellow River was divided as 14 sub – regions. Using the model to solve the project construction sequence, the sequence scheme of the water project construction was achieved. The results have an important significance for the different water projects construction of the downstream of the Yellow River.

**Key words:** ideal points methods, fuzzy decision making, project sequence, yellow river

## 1 Introduction

The project planning and construction sequence are the important contents for river channel improvement and water conservancy development of the downstream of the Yellow River. The infrastructure construction sequence will play a very important action in social and economical development. At present, the methods of engineering sequence planning include mainly analysis hierarchy planning (AHP), synthetic quantitative comparison, entropy decision making and optimum methods, etc. Qu Dayi, etc. (2000) applied the method of AHP to construction sequence of highway network planning and realized quantitative experience of decision – makers, which plays important significance in treatment of complex structures and shortage of necessary data. Chen Peng, etc. (2004) applied the method of comprehensive quantitative comparison to construction sequence of urban main road, and converted qualitative objectives to quantitative value, and substituted different qualitative multi – purpose by single purpose and selected sequential scheme based on synthesized single value. Liao Yong (2005) applied entropy decision making method to selection of evaluation indicator weight to reduce subjective error of indicators weight in 8 regional water resources development sequence of Yunnan Province.

The present paper applied fuzzy decision making theory and ideal points methods to set up fuzzy ideal point model. Based on the data of water conservancy construction systems and considering different keystones of the regional water conservancy in the regions of the lower reaches of the Yellow River, the different indicator weights were calculated. Through scheme optimization, the water conservancy construction sequence was evaluated.

## 2 Fuzzy ideal points methods

### 2.1 Ideal points methods

For a multi – objective problem, set the objective  $F(x) = \{f_1(x), f_2(x), \dots, f_m(x)\}^T$ , and its

relative objective weight  $W = \{w_1, w_2, \dots, w_m\}^T$ . Considering a scheme set  $P = \{p_1, p_2, \dots, p_n\}^T$  with character value  $x_{ij}$  for scheme  $P_i$  for objective  $f_j(x)$ , then, the matrix of purpose character is as follows;

$$X = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1m} \\ x_{21} & x_{22} & \cdots & x_{2m} \\ \vdots & \vdots & & \vdots \\ x_{n1} & x_{n2} & \cdots & x_{nm} \end{bmatrix} = (x_{ij}) \quad (1)$$

In the matrix of objective character, the extreme values for different column  $\bigwedge_i x_{ij} = \max_i x_{ij}$ ,  $\bigvee_i x_{ij} = \min_i x_{ij}$ , in which,

$$x_j^* = \begin{cases} \bigwedge_i x_{ij}, \text{for optimum maximization} \\ \bigvee_i x_{ij}, \text{for optimum minimization} \end{cases} \quad (2)$$

Then, the ideal points can be got from character matrix, i. e.  $x^* = \{x_1^*, x_2^*, \dots, x_m^*\}$

According to Minkowski's distance method

$$\|F(x) - F^*\| = \left\{ \sum_{j=1}^m w_j [f_j(x) - f_j^*]^p \right\}^{1/p} \rightarrow \min \quad (3)$$

the distance between every actual scheme and ideal scheme is,

$$d_i = \left\{ \sum_{j=1}^m w_j (x_{ij} - x_j^*)^p \right\}^{1/p} \quad (4)$$

To make sequence of  $d_1, d_2, \dots, d_n$ , the scheme relative to the minimum value could be considered as the optimum scheme. In Eq. (4), the distance relative to  $p = 1$  was defined as absolute distance, and the distance relative to  $p = 2$  was defined as optimum distance, when  $p \rightarrow \infty$ , the distance was defined as Cepistove distance.

## 2.2 Fuzzy decision making analysis theory

The following principles were defined in a set  $D = \{d_1, d_2, \dots, d_m\}$

(1) If  $d_i$  is more important than  $d_j$ , then,  $e_{ij} = 1, e_{ji} = 0$ ;

(2) If  $d_i$  and  $d_j$  are same important, then  $e_{ij} = e_{ji} = 0.5$

According to the definition, the dual comparison matrix was obtained as follows,

$$E = \begin{bmatrix} e_{11} & e_{12} & \cdots & e_{1m} \\ e_{21} & e_{22} & \cdots & e_{2m} \\ \vdots & \vdots & & \vdots \\ e_{m1} & e_{m2} & \cdots & e_{mm} \end{bmatrix} \quad (5)$$

To sum up every rows of the matrix, and to rearrange each row in order from large to small, then, a sequential consistent standard matrix was obtained as follows,

$$\beta = \begin{bmatrix} \beta_{11} & \beta_{12} & \cdots & \beta_{1m} \\ \beta_{21} & \beta_{22} & \cdots & \beta_{2m} \\ \vdots & \vdots & & \vdots \\ \beta_{m1} & \beta_{m2} & \cdots & \beta_{mm} \end{bmatrix} \quad (6)$$

The matrix above can satisfy the definition as well.

Considering the first row in the sequential consistent standard matrix, we obtain

$$0.5 = \beta_{11} \leq \beta_{12} \leq \cdots \leq \beta_{1m} \leq 1 \quad (7)$$

$\beta_{1i}$  is the important comparison value for the  $i$ th region, it can be checked up from Table 1 relative to different attitude indicators.

Each regional weight could be calculated from fuzzy standard values, that is,

$$w_i = \frac{w'_i}{\sum_{i=1}^m w'_i} \quad (8)$$

In which,  $w'_i = \frac{1 - \beta_{li}}{\beta_{li}}, i = 1, 2, \dots, m$ .

**Table 1 Relationship between attitude indicators and fuzzy standard and subjection grade**

Attitude indicators	The same	slight			normal	serious		
Fuzzy grade	0.50	0.525	0.55	0.575	0.60	0.625	0.65	0.675
Subjection grade	1.0	0.905	0.818	0.739	0.667	0.60	0.538	0.481
Attitude indicators	obvious	distinct			quite	extraordinary		
Fuzzy grade	0.70	0.725	0.75	0.775	0.80	0.825	0.85	0.875
Subjection grade	0.429	0.379	0.333	0.290	0.25	0.212	0.176	0.143
Attitude indicators	very	extreme			unexampld			
Fuzzy grade	0.90	0.925	0.95	0.975	1.0			
Subjection grade	0.111	0.081	0.053	0.026	0			

### 3 Engineering sequence of “eleventh – five years” in the lower reaches of the Yellow River

#### 3.1 Structures of scheme set

The water conservancy engineering in the lower reaches of the Yellow River include levees, water diversion, irrigation and water saving, soil conservation and ecological structures, river mouth comprehensive development and water information projects, etc. in which, flood control and water diversion structures account for large proportion. 33 schemes were evaluated in the study. Each scheme was formed based on the regional features and different types of structures. There are more than 300 items relative to each scheme.

#### 3.2 Objective evaluation systems

There are 17 evaluation objectives of water conservancy construction sequence in the lower reaches of the Yellow River, i. e., the length of levees, the length of river improvement, the length of flood detention dykes, total volume of the reservoirs, flood control volume of the reservoirs, annual water supply for urban areas, water supply for agricultural and urban population, newly developed irrigation area, irrigation improvement area, newly developed water saving irrigation area, newly developed water – logging prevention area, improvement of water – logging prevention, river mouth regional comprehensive project development, soil and water conservation harness area and total engineering investment, etc. (see Table 2).

#### 3.3 Regional weight

According to regional structure features, hydraulic engineering construction in the downstream of the Yellow River was classified as 14 sub – regions, i. e. Zhengzhou, Kaifeng, Jiaozuo, Xinxiang, Puyang of Henan Province and Heze, Jining, Taian, Jinan, Zibo, Weifang, Liaocheng, Dezhou, Binzhou and Dongying of Shandong Province. All the regions have their own keystone planning with water diversion projects from the Yellow River as the important structures. With the Dawenhe basin of Taian prefecture reservoir hydraulic structures are key construction contents. In each regional engineering construction, urban water supply structures need to be considered in preference. Urban and rural water supply and eco – environment engineering construction need also to be considered. Water diversion projects for outside water use of the Yellow River basin were

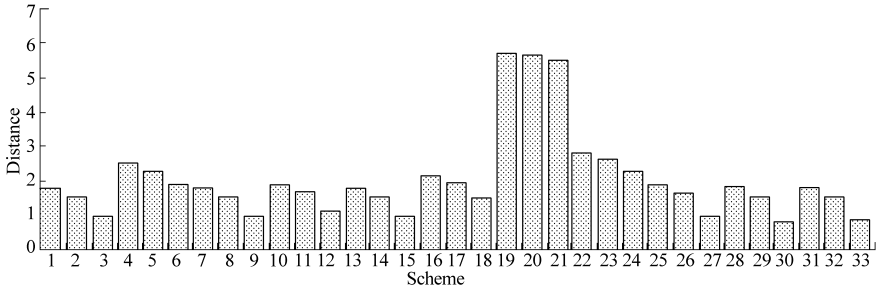


### 3.4 Results

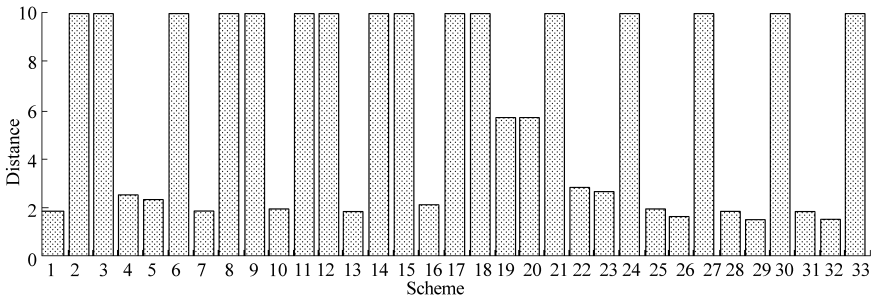
The optimum distances were calculated with Eq. (4), in which, the objective character value of the scheme  $x_{ij}$  is as follows:

$$x_{ij} = \sum_{l=1}^{l_i} r_{lj} \times w_j \quad (9)$$

Where,  $l_i$  is the number of structures in the its scheme,  $r_{lj}$  is the character value of the  $j$ th objective relative to the project  $l$  in the  $i$  scheme,  $w_j$  is the weight of the  $j$ th objective relative to the project  $l$  in the its scheme, which need to be evaluated according to different regions, see Table 3. After calculation of character value of the different schemes, the optimum distances of the scheme can be calculated, see Fig. 1 and Fig. 2.



**Fig. 1 Optimum distance of different schemes for full investment**



**Fig. 2 Optimum distance of different schemes for 95% of budget**

It can be seen from Fig. 1 and Fig. 2 that the 30th scheme is the best one when the investment is perfectly satisfied. When the investment is less than 95% of the budget, the 29th scheme is the best one, and the 32nd scheme is considered as the second one, and most schemes can not meet the demand of investment. When the investment is less than 90% of the budget, the 25th and 28th can meet the demand.

The reasonable analysis was carried out based on Fig. 1. In Fig. 1, the 30th, 9th, 15th, 33rd, are the optimum schemes, which have the common features that all the Yellow River levees, large water diversion structures, irrigation projects in large irrigation districts, key eco – environment projects, river mouth comprehensive harness projects and key reservoirs need to be constructed. The 19th, 20th and 21st schemes are undesirable schemes, which have the common features that important large water diversion projects, eco – environment and river mouth harness projects have not been included in the schemes. The comparison of optimum and undesirable schemes shows that levee structures, Yellow River diversion irrigation structures, key water saving projects rehabilitation in large irrigation districts and river mouth comprehensive harness should play an important role in the industrial and agricultural production of the downstream of the Yellow River. It will meet the demand of “eleventh – five years” water resources development of Henan and Shandong provinces in

the downstream of the Yellow River.

#### 4 Results

The water conservancy construction sequence was made by using fuzzy ideal point method in the paper. The schemes obtained can be considered as the reference indicators for the “eleventh – five years” water resources planning and development of Henan and Shandong provinces in the downstream of the Yellow River. The process of method application would play reference value in similar project construction sequence.

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## Application of Geo – materials in Flood Defense Works

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**Abstract:** Geo – Materials has the functions of drainage, filtration, anti – seepage in flood defense with the characteristics of holistic strength, rapid response, wide adaptability, convenient store and carry, cheap expense, wear well and recycling. Geo – Materials can rapidly relief the dangers such as the collapse of embankment, pipe surge of the foundation, tumbling hole of the body of embankment, scattered seepage in the slope backward water, escaping from the slope backward water, overflowing and scouring of engineering works, breaking.

**Key words:** Geo – Materials, flood defense, dikes

### 1 Application status

As a new type of geotechnical engineering material, Geo – Materials consists of synthetic fiber, plastic and synthetic rubber and can be made various types of products, which are put into inner, surface and medium between layers to take engineering effects. Geo – Materials can meet the requirements for materials in flood defense, for example light weight, easy conveyance, non – putrescibility, simple construction, rapid effectiveness. The features of Geo – Materials can meet the requirements for flood defense exactly. It is a newly developed technology to apply the Geo – Materials to geotechnical engineering in recent 50 years and it is introduced into China in the end of 1970s. In 1985, huge pipe surge destroy was occurred for left bank slope foot in Luliang, Yunnan Province during flood season. The dangerous situation was eliminated by using adhesive – bonded Geo – Materials as the filtration layer with rubble pressing on the top. Following that, Geo – Materials has been used to eliminate the dangerous situation on the dikes along middle and downstream of Yangtze River and northern China rivers, as well as slope & bank protection works have been carried out. The State General Flooding Defense & Drought Fighting Headquarters put the Geo – Materials as the flooding defense and quick responding material since 1991 to issues the tasks of production and storage. Intertexture bag, compound cloth, soil engineering texture, anti – waving cloth (i. e. intertexture cloth covering membrane) etc. have been stored in various drainage areas. During the flooding defense in middle and downstream of Yangtze River and Taihu Lake drainage area, 30,000,000 pieces of soil filled bags which knitted with Geo – Materials were used in Jiangsu and Anhui provinces only. And over 100,000,000 pieces of intertexture bag, 14,000,000 m<sup>2</sup> intertexture cloth and 2,860,000 m<sup>2</sup> adhesive – bonded cloths were used during the flooding defense in Yangtze River and Songhuajiang River of 1998.

### 2 Common used Geo – Materials in flood defense

Geo – Materials is mainly classified into Geo – Materials and soil engineering membrane, representing permeable material and non – permeable synthetic material respectively. The Geo – Materials is further classified into four types: basketwork, woven fabric work, adhesive – bonded fabric works and synthetic fabric works. The present variety of Geo – Materials for more popular application are intertexture bag, intertexture cloth, adhesive – bonded cloth and soil engineering membrane (or synthetic soil engineering membrane). During the flood defense, its functions of drainage, reverse filtering and anti – seepage are mainly used to handle the dangerous situations such as collapse, pipe surge, fluid soil and landslip. Due to the different material types, its reverse

filtering and drainage effects have much difference. Therefore, the Geo – Materials features mechanism shall be analyzed to choose the right Geo – Materials based on the actual situation at the emergent place and granularity& aggregate of the protected soil to ensure successful emergency dealing.

### **3 Function and scope of application for Geo – Material**

Any material or product has its certain application scope and this application scope is defined by its function. For the application of Geo – Materials in water conservancy projects and other relevant projects, there are several kinds of functions concluded; reverse filtering, drainage, protection, reinforcing, isolation etc. In addition, Geo – Materials can be used together with other material to form a compound non – permeable fabric for penetration prevention. The main function of soil engineering membrane is anti – seepage.

#### **3.1 Reverse filtering function**

Geo – Materials has a very good permeable performance with appropriate sized pores. So the water pass – through requirements not only can be met, but also the pipe surge and loose soil destroy due to base soil grains over loss can be prevented. With this function of Geo – Materials, the traditional grit reverse filtering layer can be replaced with Geo – Materials in actual projects. For example, the reverse filtering layer ( mat base) of dyke slope protection, the reverse filtering layer of embankment backward drainage, the reverse filtering layer of culvert gate outlet slope protection and reverse filtering for pressure reducing drainage well, etc. .

#### **3.2 Drainage function**

Geo – Materials has very good drainage capability vertically and horizontally. And the regulation can be made also. So, it can be put as the drainage facility effectively to collect the water content in the soil and drain. For example, the drainage of retaining wall, vertical and horizontal drainage inside of embankment as well as the drainage for speeding up soil solidification. The drainage function of Geo – Materials is always combined with reverse filtering function to play the role of both sides.

#### **3.3 Protection function**

With the good mechanics property and permeability, Geo – Materials can be used to prevent flushing erosion and keep the base soil from destroying due to outside influence. For example, base mat of dyke slope protection, riverside foot protection, sea board or tide – proof bank protection, protecting slope foot from washing out as well as flood prevention& emergency dealing, etc.

#### **3.4 Reinforcing function**

Geo – Materials can be buried into soil so that the soil body lateral displacement can be limited with the friction between fabric and soil body. This is equivalent to apply lateral pressure increment, thus the soil body strength can be improved and the bearing capacity is increased. Reinforcement diffuses the stress and this helps to adjust groundsill settlement. For example, reinforcement of soft soil ground or insufficient strength ground for dyke and various structures, temporary road building on frozen earth and watery soil, preventing asphalt concreting road from cracks, building reinforced soil wall, stabilizing road – side slope, and preventing the landslip caused by frozen or melting and other activities.

#### **3.5 Isolation function**

The isolation function for Geo – Materials is to isolate the material to prevent the mixing each

other, or as the isolation layer of the same material for some purpose. With the isolation layer, the stress diffusing can be arisen so that the ground settlement will be equalized for certain degree. The isolation provides drainage section to speed up ground concretion and increase bearing capacity. The isolation may prevent the phenomena such as frost boil, etc. , for example, the isolation layer between various interfaces for different materials such as earth& stone dam, dike and embankment.

### **3.6 Anti – seepage function**

The Geo – Materials can become non – permeable fabric after immersed or brushed with some waterproof material such as ethylene resin, synthetic rubber, polyurethane or plastic. Thus, it is same as soil engineering membrane and can be used in various anti – seepage constructions. Further more, it has more advantages in mechanics and hydraulics properties. Non – permeable fabric and soil engineering membrane have been popularly applied to anti – seepage and waterproof projects such as dyke, reservoir, water pond, channel, house surfaces and underground caverns. It can also be used as water stoppage with water or air filled under the condition that construction stiffness is met.

## **4 Application instances for Geo – Materials in flood defense and emergency dealing**

About how to utilize Geo – Materials to deal with emergent situations, concrete analysis need to be made according to actual situations. I’ d like to introduce more on the application instances for Geo – Materials in flood defense and emergency dealing as follows.

### **4.1 Overflow prevention and emergency dealing**

The Geo – Materials can be used to protect embankment and top of dam from overflowing and the main emergency dealing methods are: increase the height of embankment and reinforce the embankment with sub – embankment of intertexture soil bags and mixture, intertexture bag and Geo – Materials, Geo – Materials and soil. The anti – washing out of intertexture soil bags, soil engineering soft raft and soil engineering membrane is utilized mainly to protect the stability of sub – embankment built during emergency dealing.

Instance: Great success has been got with flood defense sub – embankment made of soil bags during the flooding period of Yangtze River, Nenjiang River and Songhuajiang River in 1998. 620 km sub – embankment was built for the dyke of Yangtze River drainage area and over 800 km for Nenjiang River and Songhuajiang River drainage areas. The height of sub – embankment is up to 2. 2 m and tens of kilometers of water are retained actually with 1. 6 ~ 1. 7 m retaining height. Additional several hundreds of million cubic meters of water was stored with sub – embankment building in Dongting Lake area thus relief the flooding burden of middle& downstream of Yangtze River.

### **4.2 Storm waves emergency dealing**

Dyke front water level will increase and water surface will become wider when the water level of rivers increases during flood season. Strong storm waves will be formed when the wind velocity is big and the wind direction is same as that of blowing stroke. With the continuous surge and withdraw washing out and the waves climb up and down the slope, the water side slop of dike will produce the vacuum action and negative pressure will occur. Thus the embankment soil material or slope protection material will be damaged or destroyed due to washing out. The water side slope of dike will become sharp ridge due to washing out for light condition; and for serious condition, dangerous situations such as collapse, landslip and overflow will be caused so that the dike body will be damaged seriously and calamity will be followed.

Instance: There was rainstorm in Dawen river drainage area from 0 o’ clock to 24 o’ clock on July30, 2001. The average rainfall ahead of Linwen is 74 mm and the maximum rainfall was 114mm

at Dongzhou hydrometric station. With the influence of rainfall in Dawen river drainage area, the flood peak flow is  $1\,050\text{ m}^3/\text{s}$  at 12:18 when the Wenhe river enter into Daicunba hydrometric station of Dongpinghu Lake on Aug. 1. The water level of Dongpinghu old lake rose to 42.91 m at 20:00 with 0.41 m exceeding warning water level and the corresponding storage is  $5.25 \times 10^8\text{ m}^3$ . After this, the water level of Dongpinghu Lake was still rising. There was another rainstorm (heavy rainstorm in some places) in Dawen river drainage area at 3 o'clock on Aug. 4, 2001. The maximum rainfall was 271 mm at Loujing hydrometric station. The flood peak flow is  $2,900\text{ m}^3/\text{s}$  at 7:00 of Aug. 5. The water level of Dongpinghu Lake was 44.38 m at 1:00 of Aug. 7 with 1.88 m exceeding warning water level and 0.38 m exceeding guarantee water level which was the maximum water level since the reservoir was built in 1960. On Aug. 7, a sub-bank was handled urgently at Baliwan breach (15+000 ~ 15+350) where the second stage dike was not increased in height. The sub-bank is about 1.0 m high and 350 m long. Texture soil bags stacking with soil engineering cloth covering outside was adopted. At 16:00 of Aug. 7, there was sudden strong wind in the old lake area of Dongpinghu Lake and the wave height was 1.5 m. The storm waves reached the dike top at Baliwan breach and two mud collecting boats which stopped in the lake were surged to dike. Since the sub-bank emergency was handled in time, the storm waves washing out was avoided.

### 4.3 Seepage (scattered soak) emergency dealing

When the high water level lasts longer time during flood season, the stream will seep towards inside of dike body under the seepage pressure. And the dike body will have two parts: upper part is dry and the lower part is wet. The interfacing line between two parts is soakage line. If the quality of dike body is not very good, there will be more water seeping into dike and the seepage line will be higher accordingly. Below the flee point at slope backward water, the soil is wet or soft and there is water comes out, this is called seepage.

Instance: Slope collapse with vertical height 2.5 m above dike inside foot was occurred within 15 m long at Shangchewan pile No. 618+859 ~ 618+865 of Yangtze River and the hanging ridge is 0.5 m high. Dike inside slope below dike top and vertical height 1m had serious scattered soak. And the water level of Waijiang river was 37.65 m at that time. The method of emergency dealing is: A. Make permeable soil support with intertexture soil bags at inner slope collapse to fill mineral sand with 0.1 m thick and crushed stones with 0.1 m thick. The dangerous situation was stabilized in general. B. Repair the front dam to stop seepage with intertexture soil bags. The front dam is 50 m long and 5 m wide with 0.5 m higher than the water level. And soil engineering membrane was laid on the front dam to prevent waves. C. Open ditches to guide the seeped water at serious scattered soak section with 400 m long. The width of ditch is 0.3 m and filled with second stage sands & stones. The dangerous situation was controlled when the water seeped out.

### 4.4 Pipe surge (flow soil) emergency dealing

During great flooding season, the dikes are operated under high water level. Seepage flow will be caused because of the water difference between water side and off-water side. If the seepage slope drop at seepage flee point is bigger than permissible slope drop, seepage damage such as pipe surge or flow soil may be occurred.

Instance: During the great flood in July of 1971, pipe surge with 30 ~ 40cm diameter occurred at dike foot of off water side in the section of Chengdawan dike for Huaihe River. The water came out as a column with 30 cm and many sand rings accumulated around the hole. For emergency dealing, non-woven Geo-Materials was adopted and the soil engineering dimension is  $5.3\text{ m} \times 5.3\text{ m}$  (length  $\times$  width) with unit mass  $400\text{ g}/\text{m}^2$ . It was put on the hole of pipe surge directly to try to stop pipe surge boiled sand. The foreseen effect was not reached at the beginning with improper way. When the stone blocks were put in the middle of fabric, its surroundings bulged out; on the contrary, when the stone blocks were put around the fabric, its middle parts bulged out again. Put additional stone material with 30 cm on it, there still was muddy water coming out. The muddy

water couldn't be stopped when the top weight was increased to 60 cm thick. The seeped water became clear when the top weight was increased to 1.0 m thick. But the muddy water came out again around the non-woven Geo-Materials after several hours. This indicated that the dangerous situation was not eliminated completely. Finally, an enclosed well with 30 m long and over 1.0 m high was built around the pipe surge and the dangerous situation was controlled.

Huaihe River had 5 times of flood peaks in 1987 with long time higher water level. There were several places which had dangerous situations such as boiled sand and water bulged out on Mengwaquan and Chengxihu store flood water dikes. Geo-Materials was adopted to cover the opening of pipe surge under urgent situation to press the boiled sand to form reverse filtering. Notably effects can be obtained in most cases if the design and construction can be made according to the technical requirements of Geo-Materials reverse filtering drainage. Generally, clear water will come out about 30 min ~ 60 min after using Geo-Materials.

#### **4.5 Leakage hole emergency dealing**

Leakage hole is the flow pass which go through dike body or dike foundation. The water flow for leakage hole is pressure pipe flow with high speed and strong washing out. The dangerous situation develops very fast. It is one of the most serious dangerous situations for dike. Especially for Yellow River, the dike is made of sand content soil and there is big difference between water side and off-water side. Therefore, there are many hidden troubles and some of them exist under deep water and can not be found easily. It is very difficult to check the troubles and to make emergency dealing.

#### **4.6 Cracks emergency dealing**

Cracks on the dike are most common dangerous situation and it may be the sign of other dangerous situation sometimes. Some cracks may be grown up to leakage holes and more attention shall be paid.

Instance: An about 1.0 cm crack was occurred at off-water side of Caishanghu dike of Qianlianghu farm yard with pile No. 32+000 ~ 32+090 on July 20, 1998. The landslide started to expand on July 18 and the maximum width of crack is 10.0 cm with 20.0 cm vertical settlement, 600 m in length. The length of most serious crack section of dike is 93 m. Measures for urgent dealing: non-permeable soil engineering membrane was used to cover slip and cracking section to prevent rain water from entering to get the dangerous situation worse; Open ditches on the slip and cracking section to guide seepage, reduce load, relief pressure and stop slipping; excavate earthwork as soil support, built a soil support every 15 m for the serious landslide section with 93 m; make sand well which similar to pressure relief well at middle and lower part of landslide to go through slip and cracking section; non-flood defense trucks were forbidden to pass through and strengthen the monitoring. The dangerous situation was controlled after treatment.

#### **4.7 Dike collapse emergency dealing**

Collapse is an important dangerous situation for dike and embankment waterside. The main conditions of collapse occurrence are: A. the strength of circumfluence is very big; B. river trend has bigger changes with "transversal river", "diagonal river" whose collapse parts are closed to main current; C. the anti-washing out capacity for dike or embankment is weak. If the collapse situations cannot be treated in time, embankment collapse disaster will be resulted.

Instance: The embankment of Yellow River Huayuankou 115 was washed out by circumfluence on Mar. 17, 1999. Its lower riverbed was washed out and the embankment slope slipped down with insufficient stability. The flow speed of main stream on site was 1.5 ~ 1.7 m/s and the water depth was 7.0 ~ 8.5 m. The emergency dealing team has 30 persons, one set of 6 inch slurry pump, a dump truck with 8t capacity and a loader. Slope protection and foot protection were carried out with

sand filled soil engineering reverse filtering cloth made long duct bag mattress. Its operation is: detect the water depth and flow velocity ahead of embankment and choose the appropriate sized soil engineering reverse filtering cloth made long duct bag mattress with end of long duct bag closed and inlet opened; then position the  $\Phi 10$  mm polyamide fiber pulling rope at 3 ~ 5 passes upstream of soil engineering reverse filtering cloth made long duct bag mattress.  $\Phi 10$  mm top anchoring polyamide fiber rope will be tied every 1.0 m on connecting reverse filtering of inlet for mattress duct bag and a  $\Phi 10$  mm polyamide fiber pulling rope will be tied at each corner of mattress. For the next step, turn it to form rolls. Roll the chosen soil engineering reverse filtering cloth made long duct bag mattress with the end of mattress as the heart of roll and put it on the embankment shoulder and surface along with protection slope. The third step is piling and fix raft. Fix the polyamide fiber rope at the top of mattress by anchoring and insert the wood piles with  $\Phi 150$  mm and 1.5 m long at corresponding embankment surface and proper position of mattress polyamide fiber pulling rope fixing. The top of wood piles is higher than embankment surface by 0.3 ~ 0.4 m. Then fix the mattress top anchoring polyamide fiber rope and pulling rope to wood piles. Finally, pumping the sand by slurry pump combined with loading soil (transported by truck and unloaded at inlet of duct bag). Fill the two duct bags firstly at upstream side of mattress, meanwhile, with the expanding of mattress during filling, tight and loose adjustment and anchorage of pulling rope at upstream and end side shall be made in time to realize the loading, filling and exact positioning of mattress. And the dangerous situation can be controlled within short time. According to the exposed mattress position after water level went down after dangerous situation, we can say that the effects of this slope protection and foot protection is much more ideal.

#### 4.8 Embankment buttress (retaining wall) collapse emergency dealing

Dangerous situation of collapse is the most common for embankment buttress. With the washing out of water flow, the phenomenon of settlement occurrence is called collapse dangerous situation. The collapse dangerous situation is divided into three types: subsidence, slipping& sinking, mound immersing. Subsidence is the phenomenon that the embankment buttress slope surface has light settlement partially. Slipping& sinking is the phenomenon that level slope has collapse and falling down completely or partially within certain scope due to loss of stability. Mound immersing means that the embankment buttress slope protection are immersed into water suddenly together with partial soil embankment. It's the most serious dangerous situation. The heavy dangerous situations such as broken embankment, collapsed embankment will occur if the protection and urgent treatment are not carried out in time.

Instance: Emergency dealing of embankment I for Yellow River Zaoshugou. The river trend was increased with great extent on Sept. 25, 1999 and the flow reached the bend ahead of Zaoshugou project thus caused the occurrence of dangerous situation at unprotected soil section foot for embankment I of Yellow River Zaoshugou. The river flow at that time was about  $1,100 \text{ m}^3/\text{s}$  and the width of river water surface was about 80m, velocity was 2.0 m/s and the depth was over 10.0 m. With the action of vortex and spiral stream, the soil embankment inside river bend was collapsed very fast. To make the emergency dealing with stone material, the foot can be protected only and the slope cannot be protected. Moreover, the project was in tender bottomland area of Yellow River and it was very difficult to collect the wicker material. It was decided to deal with the dangerous situation using four soil engineering reverse filtering clothes made long duct bag mattresses for sand filling. The process and method is similar to that for Huayankou 115 embankment protection; chose the mattress - tie the ropes and make rolls - piling and fix raft - filling and loading. The different point is that the dangerous situation is more serious and urgent than that of Huayankou 115 embankment protection. The slurry pump was used to pump the mud& sand in project off water bottomland and embankment crotch to fill mattress duct bag. Manpower was adopted to fill the soil which brought by truck and put at the inlet of mattress duct bag together with slurry into mattress duct bag directly. At the meantime, manpower was required to throw the intertexture soil bags into mattress duct bag also. The high strength woven soil engineering reverse filtering cloth made long

duct bag mattress will quickly roll down along the embankment slope and expand under the action of slurry, soil and soil bags weight to stick to embankment slope and riverbed surface. Under the action of polyamide fiber pulling rope, the mattress sunk smoothly according to design state although there were many vortex and spiral streams ahead of embankment. Finally, the soil engineering reverse filtering cloth made long duct bag mattress was laid on the preset position exactly and the dangerous situation was controlled quickly.

#### **4.9 Emergency dealing for construction cut off**

Instance: A method that fill long duct bag to protect bottomland, cage with intertexture bag entering, heavy strength earthwork following up to stop airflow was adopted in IV section of South – to – North Water Diversion project on Dec. 18 of 2005. And the main stream of river was cut off successfully relying on the tender bottomland in the river center. Adopting the traditional methods such as protect bay using embankment and guide water using bay to combine with the method that filling long duct bag at the sections which are washed out heavily to make the protection actively so that a soil construction platform without any stones withstood the water& sand regulation water head of 3,800 m<sup>3</sup>/s flow. The bold application of innovated technology ensures the construction of main project. And the construction scheme of traditional wicker stone case entering to protect embankment is optimized also.

### **5 Evaluation of Geo – Materials**

The practice proves that Geo – Materials has its obvious advantages in the aspects of embankment protection, slope protection, sub – embankment urgent repairing, leakage hole blocking in emergency, pipe surge and seepage treatment of dyke off – water side in flood defense projects.

#### **5.1 High integrity**

The Geo – Materials can be manufactured to long duct bag, long duct mattress and soft raft, etc. . These products can be chosen as per the type and size of dangerous situation. The partial washing out does not occurred easily. It can adapt the riverbed washing to deform and play very good role in protection.

#### **5.2 Quick emergency dealing**

Racing against time is extremely important in Yellow River flood defense. Flood defense projects will be ensured to tide over the flood season safely if the repair tasks can be finished before the arrival of flood. On the contrary, flood disaster will be caused and the losses will be resulted.

#### **5.3 Wide adaptability**

After the woven Geo – Materials soft raft is sunk down, it can match with the river embankment (dike slope) with various landforms very well. And it can also adjust its position following riverbed section changes by washing out to contact the embankment slope closely and play the role of washing prevention and embankment protection. Meanwhile, it can be used as very good filtering layer when there is pipe surge dangerous situation at off – water slope.

#### **5.4 Simple operating during emergency dealing**

It is effective through practice and application. Several pieces of soil engineering cloth may be used to handle a dangerous situation very quickly and effectively sometimes. We can say that it is

simple, quick action and has good result. Thus the transportation of sand which required for reverse filtering, crushed stones, wicker and other material in large quantity for a long distance is avoided

## 6 Concluding remarks

The general office of State General Flooding Defense& Drought Fighting Headquarters made lots of application and research works in recent two years in order to conduct a better utilization of Geo – Materials in flood defense. Relevant institutes are organized to develop the high – friction soil engineering intertexture bags and the achievement has been approved with acceptance. After the great flood of 1998, researches are carried out on the application of Geo – Materials in emergency dealing of pipe surge. The researches emphasize on the mechanism and construction machines & tools of Geo – Materials in emergency dealing of pipe surge. And the research on construction machines& tools of soft raft is made especially with preliminary achievement. Although the application of Geo – Materials in China starts far on in time, it develops very fast. For example, the experiment& research as well as practical application on Geo – Materials soft raft in flood defense and emergency dealing is leading in the world. Social and economic benefits is remarkable due to its simple method, capital required less than that of traditional way and far less transportation of sand & stone material especially.

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## Analysis on Required Runoff to Maintain the Main Channel for Medium Flood in the Lower Weihe River

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**Abstract:** Weihe River is the biggest tributary of the Yellow River. Medium and small flood disasters frequently occur due to the serious lack of water in the recent years, sedimentation, main channel shrinkage and serious deduction of discharge capacity. In order to reduce the pressure on flood prevention, it is necessary to shape and maintain a certain river channel for medium flood in the Lower Weihe River. According to the requirement on the discharge capacity of the Lower Weihe River channel by sustainable development of social economy, analysis on the frequency of medium flood and forecasting of runoff and sediment in future, the paper discusses the standard of the main channel for medium flood, annual runoff, water volume in flood season and flood volume that is required to maintain the main channel for medium flood in the Lower Weihe River. It is hoped to give reference to trans - basin water transfer and analysis on required water volume of intake area.

**Key words:** main channel for medium flood, required runoff, bank - full discharge, Lower Weihe River

The weihe River is the largest tributary of the Yellow River, which originates from Niaoshu Mountain, Weiyuan County, Gusu Province. It goes, from west to east, along Wudi, Gangu and Tianshui of Gansu Prov., and enters into Shaan'xi Province at Fenggeling, then it passes through Baoji, Yangling, Xianyang, Weinan, and pours into Yellow River at Tongguan. The catchment area is 134,800 km<sup>2</sup>, in which Gansu Prov. takes up 44.1%, Ningxia takes up 5.8% and Shaan'xi Prov. takes up 50.1%. Its trunk stream is 818 km long. The upper reach, from headstream to Baoji, is 430 km long, with narrow channel and rushing flow; the middle reach, between Baoji Gorge and Xianyang, is 180 km long, with wide channel, sandbanks and scattered flow, the lower reach, from Xianyang to the estuary, is 208 km long, with small gradient and gentle flow.

The lower reach of Weihe River has concentrated cities, rich tourist resources and developed industry and agriculture, which is the political and economical center of Shaan'xi Prov. and important area in the Grand Western Development Program. From 1990s, medium and small flood disasters frequently occur due to the serious lack of water, sedimentation, main channel shrinkage and serious deduction of discharge capacity. The flood disasters of "92 · 8", "96 · 7", "2000 · 10" and "2003" hereby occurred with features of "small flow rate, high water level and serious disasters". In order to promote the harmonious co - existence between man and nature and reduce the pressure on flood prevention, it is necessary to keep a certain flood discharge capacity of the main channel in the Lower Weihe River.

### 1 Standard of the main channel for medium flood in the Lower Weihe River

The weihe River is an economic artery of Shaan xi Guanzhong Region. A healthy river channel is one of the key factors of sustainable development. One of the goals of social economy development in Guanzhong Region is to improve the ecological environment of the Lower Weihe River and promote the harmonious coexistence of man and nature. The requirements on flood discharge

capacity of the Lower Weihe River are: the first, average frequent flood will not produce over high water level and less flood disasters; the second, flood discharge capacity can be recovered to a certain degree, and the risk of frequent flood and super – standard flood can be controlled within the compass; the last, the transportability of sediments of river channel closes or reaches to a balance state to avoid continuous uplift of riverbed, and the flood control standard of the harnessing projects of the Lower Weihe River cannot be lowered over quickly in near future.

Recovery of ecological functions of riverbed is mainly reflected on recovery of flood discharge capacity of main channel because it not only improves the flood discharge capacity, lowers the water level of medium and small floods and reduces the uplift of floodplain, but releases the pressure of lowering flood control standard of the harnessing projects caused by floodplain uplift. Hereby the control target is proposed: flood discharge capacity of the main channel at Huaxian Station will be maintained to be 3,000 m<sup>3</sup>/s approximately, obvious uplift of floodplain in river channel will not occur.

The main channel shape of the Lower Weihe River is co – acted by the conditions of water and sediment entered into the lower reach and boundary conditions of riverbed. Under certain boundary conditions, water and sediment conditions will be the control factor that shapes the riverbed. The principle of river channel harnessing in the Lower Weihe River is to design regulation line and arrange works of leading water flow and protecting floodplain according to the main channel for medium flood. The flood discharge capacity near Lintong and Huaxian Stations is 3,500 m<sup>3</sup>/s and 3,000 m<sup>3</sup>/s respectively.

In addition, after the flood return period is analyzed, it can be seen that the return period of the peak discharge over 3,000 m<sup>3</sup>/s is 2.5 years in the period (1950 ~ 2003) at Huaxian Station, the return period of the peak discharge over 3,500 m<sup>3</sup>/s is 2.8 years in the period (1950 ~ 2003) at Lintong Station, and most of them are frequent flood. If the main channel of the Lower Weihe River is shaped as bank – full discharge 3,000 m<sup>3</sup>/s and 3,500 m<sup>3</sup>/s at Huaxian section and Lintong section respectively, it will basically meet the conditions of the main channel for medium flood.

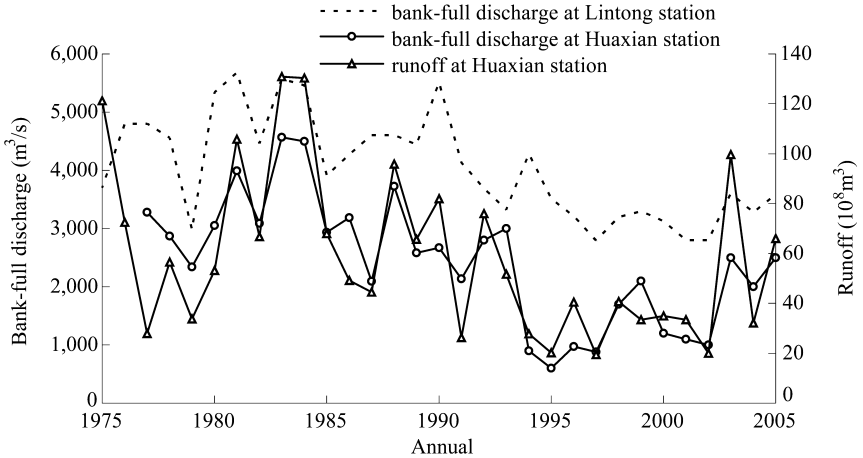
Due to the huge variation of the conditions of water and sediment since 1990s, the coming water volume in the Lower Weihe River has been reduced largely. The occurrence rate of serious flood is lowered sharply, and maximum peak discharge is decreased obviously as well. Therefore, the bank – full discharge target of the main channel for medium flood can be reduced to 2,500 m<sup>3</sup>/s and 3,000 m<sup>3</sup>/s at Huaxian and Lintong respectively.

## 2 Analysis on required runoff to maintain river channel for medium flood in Lower Weihe River

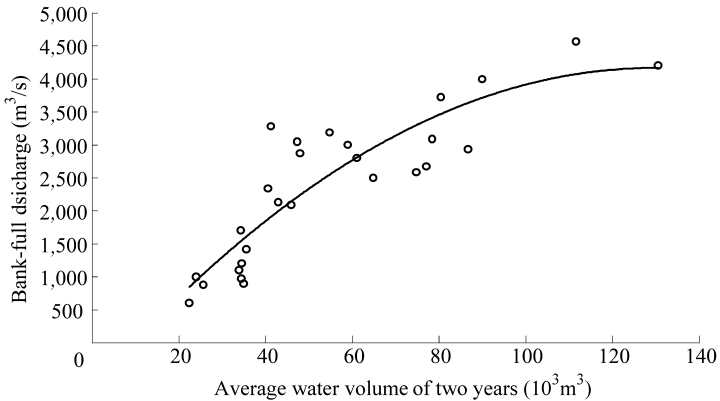
To maintain the main channel shape of the Lower Weihe River, it requires a certain amount of runoff and discharge process. From the bank – full discharge of the Lower Weihe River and runoff variations of Huaxian Station ( Fig. 1 ); big water supply corresponds with the big bank – full discharge, and vice versa. Between 1985 ~ 1993, bank – full discharge of Huaxian Station was floated around 3,000 m<sup>3</sup>/s with 3,700 m<sup>3</sup>/s in maximum, 2,100 m<sup>3</sup>/s in minimum and 2,800 m<sup>3</sup>/s in average. At this period, mean annual runoff of Huaxian Station was 6.2 billion m<sup>3</sup> and mean runoff in flood season is 3.5 billion m<sup>3</sup>. Between 1980 ~ 1983, bank – full discharge at Huaxian Station was floated around 3,000 m<sup>3</sup>/s with 3,990 m<sup>3</sup>/s in maximum, 3,049 m<sup>3</sup>/s in minimum and 3,376 m<sup>3</sup>/s in average. At this period, mean annual runoff of Huaxian Station was 7.5 billion m<sup>3</sup> and mean runoff in flood season is 5.2 billion m<sup>3</sup>. From above, it is concluded that bigger bank – full discharge requires bigger runoff and smaller bank – full discharge requires smaller runoff.

From the relationship of bank – full discharge and slip average runoff at Huanxian Station, it is found that the bank – full discharge and annual runoff are well related with slip average runoff in flood season of two years at Huaxian Station with related coefficient over 0.86. Taking account of

that the water volume of the current year and the past year has a different influence on the current bank – full discharge, it is found that there is a good relationship between the bank – full discharge at Huaxian Station, and the combinatorial water volume (0.7 times of the current year add 0.3 times of the past year) and both of the correlative coefficient exceed 0.88 as shown in Fig. 2 and Fig. 3. If the bank – full discharge at Huaxian section is maintained at 3,000  $\text{m}^3/\text{s}$ , it requires annual runoff 5 ~ 8 billion  $\text{m}^3$  approximately, about 6.5 billion  $\text{m}^3$  in average. In which, it requires runoff 3.0 ~ 5.4 billion  $\text{m}^3$  in flood season and 4.2 billion  $\text{m}^3$  in average. If 2,500  $\text{m}^3/\text{s}$  of bank – full discharge is kept, it requires annual runoff 4 ~ 7 billion  $\text{m}^3$  approximately, about 5.5 billion  $\text{m}^3$  in average. In which, it requires runoff 2.5 ~ 4.5 billion  $\text{m}^3$  in flood season and 3.5 billion  $\text{m}^3$  in average.



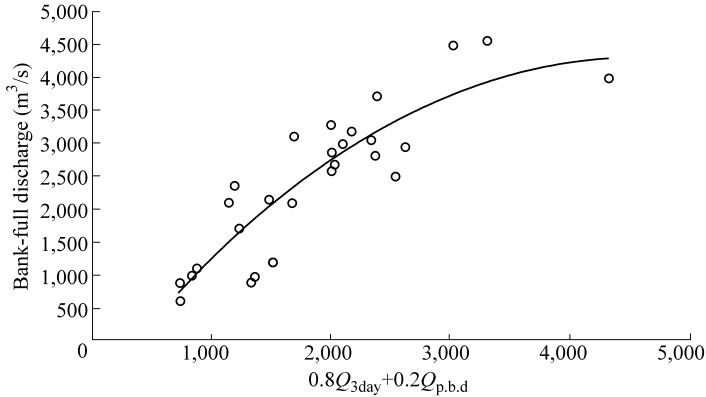
**Fig. 1** Variation of the annual runoff and bank – full discharge at Huaxian Station in the Lower Weihe River since 1974



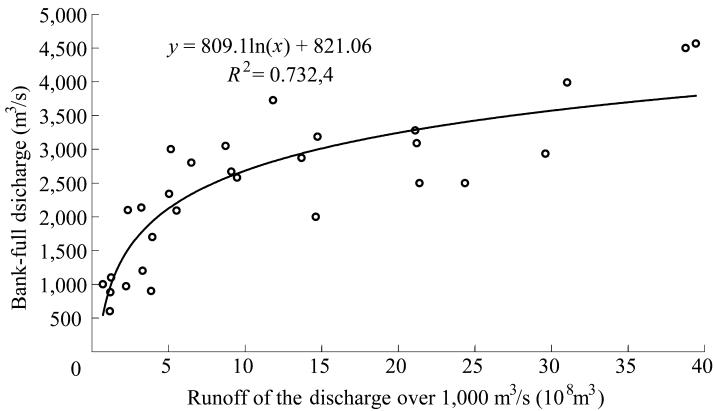
**Fig. 2** Relationship of the bank – full discharge and moving average runoff of two years at Huanxian Station

The Fig. 4 is the relationship of bank – full discharge of Huaxian Station and flood runoff over 1,000  $\text{m}^3/\text{s}$ . It can be seen that the bank – full discharge at Huaxian Station is also well related with flood runoff over 1,000  $\text{m}^3/\text{s}$ . It accounts that bigger flood is important factor to shape the riverbed. From Fig. 4, if the bank – full discharge at Huaxian section is maintained as 3,000  $\text{m}^3/\text{s}$ , it requires flood runoff that over 1,000  $\text{m}^3/\text{s}$  in flood season 1 ~ 2 billion  $\text{m}^3$  approximately, about 1.5 billion  $\text{m}^3$  in average. If the bank – full discharge is maintained as 2,500  $\text{m}^3/\text{s}$ , it requires

flood runoff that over 1,000 m<sup>3</sup>/s in flood season 0.5 ~ 1.1 billion m<sup>3</sup> approximately, about 0.8 billion m<sup>3</sup> in average. The amount of water volume in flood season also depends on discharge. Without out - of - floodplain, bigger discharge requires less water volume, on the other hand, smaller discharge requires more water volume.



**Fig. 3 Relationship of bank – full discharge and slip average runoff in flood season of two Years at Huanxian Station**



**Fig. 4 Relationship of bank – full discharge related to water volume over 1,000 m<sup>3</sup>/s in flood season at huaxian station**

### 3 Conclusions

(1) The standard of the main channel for medium flood is proposed according to flood control requirement by sustainable development of social economy, analysis on medium and frequent flood and conditions of water and sediment in future. The standard is the main channel for bank – full discharge 3,000 ~ 2,500 m<sup>3</sup>/s at Huaxian Station and 3,500 ~ 3,000 m<sup>3</sup>/s at Lintong Station.

(2) If the bank – full discharge at Huaxian section is maintained as 3,000 m<sup>3</sup>/s, it requires annual runoff 5 billion ~ 8 billion m<sup>3</sup> approximately, about 6.5 billion m<sup>3</sup> in average. In which, it requires runoff 3.0 ~ 5.4 billion m<sup>3</sup> in flood season and 4.2 billion m<sup>3</sup> in average, it requires flood runoff that over 1,000 m<sup>3</sup>/s in flood season 1 ~ 2 billion m<sup>3</sup>, about 1.5 billion m<sup>3</sup> in average.

If 2,500 m<sup>3</sup>/s of bank – full discharge is kept, it requires annual runoff 4 billion ~ 7 billion m<sup>3</sup>, about 5.5 billion m<sup>3</sup> in average. In which, it requires runoff 2.5 billion ~ 4.5 billion m<sup>3</sup> in

flood season and 3.5 billion  $m^3$  in average; it requires flood runoff that over 1,000  $m^3/s$  in flood season 0.5 ~ 1.1 billion  $m^3$ , about 0.8 billion  $m^3$  in average.

(3) The runoff to maintain the main channel for medium flood is drawn under the average incoming sediment conditions over the years. The conclusion is tentative. The shaping of the main channel for medium flood requires not only a certain water volume, but a process of runoff and sediment. A further research shall be made on the process of runoff and sediment.

### Acknowledgements

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# Research on Volatilization Characteristics of Naphthalene and 2,6-Di-tert-butyl-p-cresol in the Yellow River Water

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**Abstract:** Based on the condition of sediment and organic contaminants in the Yellow River, volatilization process of naphthalene and 2,6-Di-tert-butyl-p-cresol (BHT) in clear water and sediment laden water of 1 g/L and 3 g/L was studied to find their volatilization characteristics. The solution concentration with the volatilization process is determined by Gas Chromatograph. Then the experiment data are fitted to curve equation. The results could be attained as follows: volatilization dynamics equation, speed constant, volatilization half life and so on. The impacts that organic contaminants property, wind speed and sediment have produced on the volatilization process are discussed. The self-purification law of volatilization provide the technology support to the level of holding contaminants and gross control.

**Key words:** naphthalene, 2,6-Di-tert-butyl-p-cresol, volatilization, transfer and transformation, sediment

Lanzhou reach is a pollution discharge intensive area of the Yellow River where the detected rate of PAHs and Hydroxybenzene is higher. According to the recent years' investigation, these organic contaminants have latency toxicity of "three cause domino effect" and biology accumulation, threatening the natural resources and people's health along the reach (Gao et al 2001; Liu et al, 2004).

Organic compounds of small solubility and big molecular easily volatilize from water to air. Volatilization is an important transfer and transformation process of organic compounds in water environment. (Deng, Wu, 2000) Many environmental chemistry workers have conducted researches on the volatilization process of organic compounds, through field and laboratory simulation testing for the rivers and lakes, and have gained a lot of data and theoretical models to provide the support for the water pollution control and water resources protecting (Hou, et al, 1997; Zhao, et al, 1990; Een, et al, 2004; Rebecca, et al, 2003). Sediment also contributes to the influence on the transfer and transformation of organic compounds. Someone studied the self-purification of oil pollutant in sediment-laden water of the Yellow River. (Hu, et al, 2001) This text studies the volatilization characteristics of PAHs and Hydroxybenzene according to the status of organic contaminants and sediment. Naphthalene and BHT stand for the two kinds of compounds. It is studied that the capability of self-purification and holding contaminants in the Yellow River to protect the water resources.

## 1 Reagents and apparatuses

**Reagents:** Naphthalene, made by Tianjin Damao Chemical Reagents Factory; 2,6-Di-tert-butyl-p-cresol, Chemical Reagents Co. Ltd., National Machine Collective; Hexane; Methanol; Sodium sulfate without water, dried 4 hours under 500 °C prior to its application.

**Sediment:** the sedimentation for the test was taken from Shichuan section of Lanzhou reach in the Yellow River in November 2004. They are frozen and dried naturally, and are used after having got rid of such foreign matters as stones and plant roots, and sifted with a sieve of 100 meshes.

**Apparatuses:** electron balance, 1,000 mL beaker electromotion blender, 250 mL funnel; fanner; anemoscope; TurboVap II nitrogen concentrator, HS-260 vibrator and Agilent 6890A gas chromatography with FID(GC).

## 2 Experimental method

### 2.1 Confecting solution

Gradually diluted method; Firstly, exactly weigh up 1.000,0 g Naphthalene and BHT, dissolved by methanol to  $10^4$  mg/L. Then it was dissolved to 200 mg/L as standard solution.

### 2.2 Volatilization process experiment

Organic compounds volatilization in clear water: It is reported that Naphthalene and BHT is 0.01 ~ 0.45 mg/L in the Yellow River in the recent years. So the water solution is confected 1.0 mg/L under room temperature of 18 °C. The 1,000 mL solution is stirred by an electromotion blender to volatilize. Theat 100 mL water is sampled every one hour with the volatilization process. It is extracted by 20 mL Hexane. Then it is dehumidified and concentrated to 1 mL. Finally, the quantitative analysis is done by GC.

Organic compounds volatilization in heavy sediment – laden water: the solution is made 1.5 mg/L according to adsorption and volatilization. The sediment quantity respectively is 1 g/L and 3 g/L. The 1,000 mL solution is airproofed and placed about 12 hours. Then it is reckoned by time. The wind speed is 1 m/s. That 100 mL water is sampled every 30 minutes and separated by 4,000 r/min. Then it was extracted and concentrated to 1 mL. Finally, the quantitative analysis is done by GC.

### 2.3 Analysis condition of GC

Chromatogram column: HP – 5 quartz capillary (30 m × 530 μm × 1.50 μm); Inject temperature: 260 °C; Split rate: 10:1; Flame Ionization Detector (FID) temperature: 280 °C; Programmed temperature: 145 °C (2 min.) 20 °C/min 180 °C (2 min) 15 °C/min 240 °C (5 min). GC shall do qualitative and quantitative analyses in line with holding time of chromatogram peak and its area, and using an external standard method determines solution concentration.

## 3 Results and discussion

### 3.1 Volatilization characteristics of Naphthalene and BHT in clear water

By simulating volatilization process of BHT in clear water, the solution concentration change with volatilization time is gained. The volatilization curve is drafted with independent variable time (h) and dependent variable solution content (mg/L). (Fig.1) The volatilization curve equation is one class dynamics equation:

$$c = c_0 e^{-Kt} \quad (1)$$

$$-\frac{dc}{dt} = Kc \quad (2)$$

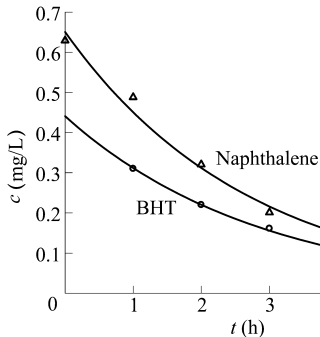
In the formula,  $c_0$  and  $c$  are organic compound concentration at initial time and  $t$  time respectively, and  $K$  is a volatilization constant.

When  $c = 0.5 c_0$ , volatilization half life  $t_{1/2} = \ln 2/K$ . Half life is inverse ratio with volatilization constant.

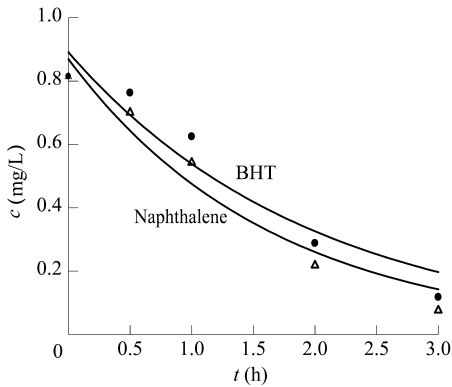
The Figure 1 obviously shows that the solution content decreases with time when the initial content of Naphthalene and BHT is certain. It could be gained that volatilization curve equation is  $c = c_0 e^{-Kt}$  with preferable relativity. The volatilization velocity is direct ratio with solution content. The bigger the solution content is, the bigger the volatilization velocity will be. With decreasing of the solution content the volatilization velocity gets slower. The parameters of curve equations and volatilization half life are presented in Table 1.

### 3.2 Volatilization characteristics of Naphthalene and BHT in sediment laden water

Transfer and transformation of organic contaminants mainly rest with compounds property and water environment. There contains sediment in natural water, to which organic compounds are easy to be adsorbed for transfer and transform. To simulate the real water situation of the Yellow River, the mixed solution of Naphthalene and BHT with sediment of 1 g/L and 3 g/L and distilled water was made up for experiments. Use the experimental data plotted a figure that curved with dynamics equation  $c = c_0 e^{-Kt}$ . The results are shown as Fig. 2 and Fig. 3.



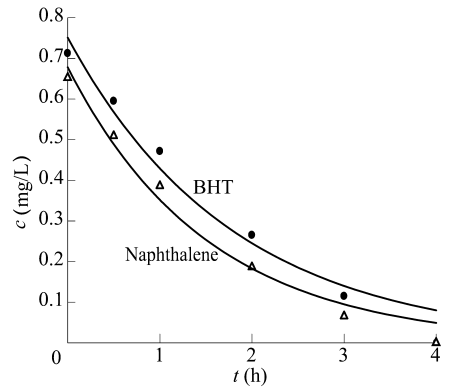
**Fig. 1 Naphthalene and BHT volatilization curve in clear water**



**Fig. 2 Volatilization curve of 1 g/L sediment**

**Table 1 The parameters of curve equation and volatilization half life of Naphthalene and BHT**

	BHT	BHT
Initial content $c_0$ (mg/L)	0.651	0.441
Velocity constant $K$ ( $h^{-1}$ )	0.367	0.347
Volatilization half life $t_{1/2}$ (h)	1.9	2.0
Relativity coefficient $R$	0.993	0.999



**Fig. 3 Volatilization curve of 3 g/L sediment**

It can be seen that volatilization curve equations are  $c = c_0 e^{-Kt}$  with preferable relativity, when the solution contains 1 g/L and 3 g/L sediment. The volatilization velocity is direct ratio with solution content. The parameters of curve equations and volatilization half life see Table 2 and Table 3.

**Table 2 Parameters of curve equations and volatilization half life about 1g/L sediment**

	Initial content $c_0$ (mg/L)	Velocity constant $K$ ( $h^{-1}$ )	Volatilization half life $t_{1/2}$ (h)	Relativity coefficient $R$
Naphthalene	0.870	0.603	1.15	0.978
BHT	0.891	0.503	1.38	0.965



**Table 3 Parameters of curve equations and volatilization half life about 3 g/L sediment**

	Initial content $c_0$ (mg/L)	Velocity constant $K$ ( $h^{-1}$ )	Volatilization half life $t_{1/2}$ (h)	Relativity coefficient $R$
Naphthalene	0.678	0.655	1.06	0.991
BHT	0.751	0.560	1.23	0.985

This indicates that the volatilization process of Naphthalene and BHT could be imitated with one class dynamics equation. Velocity constants increases and volatilization half life shortens with sediment increases. Volatilization velocity constant of Naphthalene is bigger than BHT because of the property of compounds.

### 3.3 Influence on volatilization velocity of wind speed and sediment

An comparison was made on the volatilization velocity constants with different wind speed and sediment content. The data are shown in Table 4.

**Table 4 Volatilization velocity constants of different conditions**

Velocity constant	$K_1$ ( $h^{-1}$ )	$K_2$ ( $h^{-1}$ )	$K_3$ ( $h^{-1}$ )
Naphthalene	0.367	0.603	0.655
BHT	0.347	0.503	0.560

**Note:**  $K_1$ —no wind, clear water;  $K_2$ —wind 1 m/s, sediment 1 g/L;  $K_3$ —wind 1 m/s, sediment 3 g/L.

Thus it could be concluded that wind speed had bigger influence on volatilization velocity. Velocity constant obviously increased with greater wind speed. According to the double film theory, there is a boundary film on each side of the inter-phase. They are gas film and liquid film. They bring resistance when compounds transfer and transform. (Deng, Wu, 2007) Wind promoted the gas flow, so compounds are volatilized rapidly with wind.

Sediment had influence on volatilization velocity, too. Velocity constant increases with more sediment content in a certain range. Sediment could adsorb various kinds of contaminates to purify water environment. At the same time, sediment as contaminates and their carrier could pollute water environment. With the volatilization process, organic compounds adsorbed on the sediment are released to the water environment. Sediment bring about many complex problems to the water quality parameters measurement and water environment quality evaluation and management.

## 4 Conclusions

The volatilization process and disciplinarian of PAHs and Hydroxybenzene in clear water and sediment content of 1 g/L and 3 g/L water have been simulated. Their volatilization process could be imitated with one class dynamics equation. Volatilization velocity was direct ratio with solution content. The volatilization dynamics equations of Naphthalene and BHT could be gained.

The compounds properties and water environment conditions are the restricting factors to the volatilization. The volatilization of Naphthalene is easier than that of BHT. Wind speed and sediment have obvious influences on the volatilization velocity.

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# Sorption and Desorption Characteristics of Naphthalene and BHT on the Sediment Sampled from Lanzhou Reach of the Yellow River

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**Abstract:** The sorption of naphthalene and BHT on the particulates and sediment in Lanzhou reach of the Yellow river was studied. The results show that the sorption of naphthalene and BHT on the particulates and sediment could reach a dynamic balance adequately within 8 h. The sorption curves of naphthalene and BHT on sediment are characterized by “S” shaped isotherm curve and can be well described by Freundlich equation. There is an obvious hysteresis and extreme residues that could not be desorbed absolutely in the desorption experiment of naphthalene and BHT. At the same time, we studied the effect of different hydrological conditions.

**Key words:** Naphthalene, BHT, particulates in water body, sorption and desorption

Flowing across Lanzhou City, the Yellow River is not only the unique water resource for domestic and industrial water supply, but also the only water body accepting the waste released by them. So it is significant to study the transfer and transformation of organic contaminants in this reach. At the same time, the Yellow River is also a most sediment laden river in the world. So the study on the adsorption and desorption of sediment to organic contaminants is an important tache of environment action of organism in the Yellow River.

PAHs is one of the 129 kinds of priority contaminants set down by the U. S. Environment Protect Bureau. It is one kind of most causing cancer chemicals in the environment. (Mcveety 1988) The survey report of 2001 reveals that detected rate of PAHs is 13.3% of all the organic contaminants in the Yellow River, only inferior to substitute benzene(14.7%)(Gao et al.2001). Hydroxybenzene is a main environment contaminant as basic materials of organic chemical industry. The recent years' survey indicates that PAHs and Hydroxybenzene are universal in the Yellow River. So we selected PAHs and Hydroxybenzene as objectives to study the adsorption and desorption of sediment to the two kinds of organic contaminants in Lanzhou reach of the Yellow River.

## 1 Experimental material and method

### 1.1 Reagents and apparatuses

Reagents: Naphthalene, Damao Chemical Reagents Factory in Tianjin; Hexane; Methanol; 2,6 - Di - tert - butyl - p - cresol, Chemical Reagents Co. Ltd. National Machine Collective; Sodium sulfate without water; dried 4 hours under 500 °C prior to its application; Standard reserve solution of Naphthalene and BHT: Firstly, exactly weigh up 1.000,0 g Naphthalene and BHT, both are dissolved by methanol to 104 mg/L. Then it is dissolved to 200 mg/L as standard solution.

Sediment: sediment is sampled from Shichuan of Lanzhou reach in the Yellow River in November 2004. They are frozen and dried naturally.

Apparatuses: Agilent 6890A gas chromatography with FID (GC), TurboVap II nitrogen concentrator, SXL - 1008 program control box electric cooker, LD5 - 10 low speed centrifugal machine, Z - 21012ZHWHY - 2102C control temperature shake bed and HS - 260 vibrator.

## 1.2 Experimental method

### 1.2.1 Adsorption dynamics experiment

Prepare a serial of 200 mL solution which includes Nap and BHT at the concentration of 1.00 ppm then, seal the bottle in the condition of 20 °C, 185 r/min and vibrate it. After a definite time, take a batch of bottle to test the concentration of Nap and BHT. The adsorption dynamics curve is shown in Fig. 1.

### 1.2.2 The experiment scheme of adsorption and desorption

Prepare a serial of solution containing of 1.00 ppm Nap and 1.00 ppm BHT with 3 g/L aqueous sediment particulates. Shaking this solution until adsorption balance is kept under the condition of sealed in 20 °C, 185 r/min. Then, separate the upper clear solution to test using acentric separating instrument at 4,000 r/min for 10 min. To draw the adsorption isothermal curves using the balance adsorbance concentration  $C_s$  and balance liquid phase concentration  $C_w$ . As shown in the Fig. 2 and Fig. 3.

The desorption experiment is implemented using 1.60 ppm Nap and 2.80 ppm BHT with 3 g/L aqueous sediment particles. After the desorption balance is reached, to replace 160 mL (80%) upper clear solution using acentric separating instrument at 4,000 r/min for 10min. Then, to test the upper clear solution and the concentration of organic compound is  $C_{w0}$ . Shaking the replaced solution in the condition of 20 °C, 185 r/min and replace it in every 24 h to attain a value of  $C_{wi}$ . Using the value of  $C_{wi}$ , we can calculate the organic compound concentration  $C_{si}$  on the sediment by the formulas 1 and 2. According to the values of  $C_{wi}$  and  $C_{si}$ , we can draw the desorption isothermal curves. The adsorption isothermal curves and the desorption isothermal curves of Nap and BHT are drawn in the same axis. As shown in Figure 2 and Figure 3.

$$\Delta Q_{i \text{ stripped}} = [C_{wi} - C_{w(i-1)}(1-r)]V_w/W_s \quad (1)$$

$$C_{si \text{ residual}} = C_{i-1s \text{ residual}} - \Delta Q_{i \text{ stripped}} \quad (2)$$

where,  $r$  is after every desorption, the percent of upper clear solution displaced;  $V_w$  is the volume of the container used in the experiment;  $W_s$  is the mass of sediment used in the experiment;  $C_{wi}$  is the concentration of organic compound in the liquid phase after every replacement;  $C_{si \text{ residual}}$  is the residual of organic compound on the sediment after  $i$  replacement.

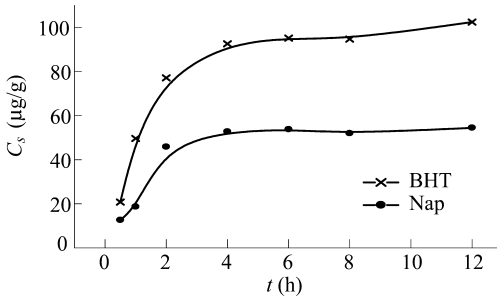
### 1.2.3 The chromatographic condition for the determination of Nap and BHT

In this paper, it is used hexane liquid extraction – gas chromatograph to analyze Nap and BHT. The instrument conditions are shown as follows: HP – 5 capillary column (30 m × 530 μm × 1.50 μm); injecting quantity: 2 μl; inlet temperature: 260 °C; detector (FID) temperature: 280 °C; split ratio; 10:1; program temperature: 145 °C (2 min), 20 °C/min to 180 °C (2 min), 15 °C/min to 240 °C (5 min).

## 2 Results and arguments

### 2.1 Determination of the adsorption time of naphthalene and BHT

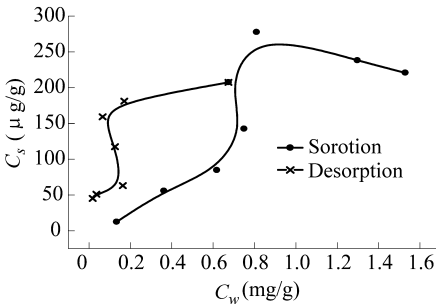
The determination of the adsorption time is the key of drawing the adsorption curve. Different compounds need different adsorption time with different sediment. It is determined the adsorption time by using 3.0 g/L of sediment concentration and 1.00 ppm of naphthalene and BHT. As shown in Fig. 1, the adsorbance of sediment fast increases in the first 2 hours and then the adsorption of naphthalene and BHT reaches balance after 4 hours ultimately. Then, as the time elapses, the organic compound concentration on the solid phase generally keeps unchanged. For the absolute adsorption balance, the balance time is set as 8 hours.



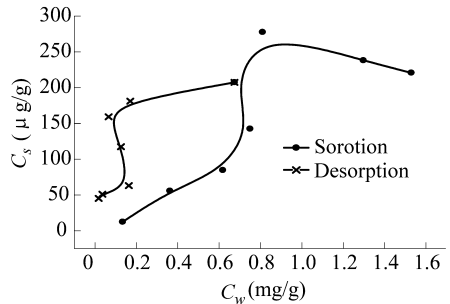
**Fig. 1 Adsorption dynamic curves of naphthalene and BHT**

**2.2 The adsorption characteristics of Nap and BHT on the sediment sampled in Lanzhou reach of the Yellow River**

The generally used adsorption isotherm curves are Langmuir, Freundlich and BET. In this paper, we drew the adsorption isotherm curve on the sediment from Lanzhou reach of the Yellow River using the data in the condition of 20 °C and 185 r/min. As shown in the Fig. 2 and Fig. 3, the adsorption curves of the two compounds are characterized by “S” model. So it can be primitively concluded that the sorption of these two compounds is multi – molecule layers adsorption. Which in the low concentration range of the curves, all display somehow linearity. We fitted the experimental data to determine whether these two adsorption curves match the three isothermal curves or not as shown in Table 1.



**Fig.2 Sorption and desorption of naphthalene**



**Fig.3 Sorption and desorption of BHT**

**Table 1 Parameters of different sorption isotherm equations Compounds**

Compounds	Form of isothermal curve								
	Langmuir isothermal curve			Freundlich isothermal curve			BET isothermal curve		
	1/kQ	1/Q	r	K	1/n	r	$\frac{1}{XmA}$	$\frac{A-1}{XmCOA}$	r
Nap	0.650	510.536	0.820	0.029	1.280	0.935	87.778	-74.114	0.627,3
BHT	0.031	17,986.125	0.841	0.040	1.398	0.944	25.732	-36.47	0.633

From the result, It can be seen that the relative coefficients of the isothermal curves of the two compounds all exceed over 0.935 and are excellent than the other two models. So the adsorption of Nap and BHT are well complied with Freundlich isothermal curve. The value of “n” in Freundlich isothermal curve reflects the no linearity degree in the adsorption course. In this experiment, the values of “n” are respectively 0.781 and 0.715. So the adsorptions of Nap and BHT all belong to no linearity adsorption.

As the opinion of literature (Wber, 1996), the difference of the sediment is the key reason for inducing the no linearity adsorption. Consequently, It can be extrapolated that the surface of the sediment from Lanzhou reach of the Yellow River takes some scrambling.

### **2.3 The desorption of Nap and BHT on the sediment from Lanzhou reach of the Yellow River**

The desorption of organic compounds from sediment can lead to second pollution, so, the study to that becomes the key factor in studying of poisonous organic compound transfer and transformation in the environment. On the basis of the study on the sorption of Nap and BHT on the sediment from Lanzhou reach of the Yellow River, we also studied the desorption course. The desorption curves are as shown in Fig. 2 and Fig. 3. From the figures, we can see that there is an obvious hysteresis in the desorption experiment. This phenomenon may be related with the chemical structure of organic compounds and the tiny holes inside sediment. The hysteresis phenomenon is reported in some papers (Chongshang et al, 2004). Kan (1997) considers that the desorption course is composed of reversible sorption and irreversible sorption, and the irreversible sorption phenomenon is the possible reason for the hysteresis.

As shown in the figures, the tail end extension of sorption curves and desorption curves can not be overlapped on the longitudinal axis. This means that the organic compound adsorbed on the particulates could not be fully desorbed so that there are residues of organic compound on the sediment. The experimental data indicate that the remainder of BHT is larger than that of Nap. As well as the structure of the sediment, the quantity of remainder is also relative with the chemical property of organic compound. As for the chemical property of the two compounds, BHT have more hydrophobicity than Nap, that this results in the small solubility and large limit remainder of BHT.

### **2.4 The effect of water temperature on the sorption**

The environmental temperature is also the important factor affecting the adsorption. In this paper, we conduct the experiments with a solution of 1 ppm at 5 °C, 15 °C and 20 °C. As a result, the balance adsorption quantity decreases with the increasing of environment temperature. This may be caused by that the increase of temperature leads to the increase of solubility of the organic compound in the water, and consequently, the adsorption coefficient decreases. So we can judge that the adsorption of Nap and BHT on the sediment from Lanzhou reach of the Yellow River is heat release adsorption.

### **2.5 The effect of sediment quantity on the sorption**

At 20 °C, we examine the effect of sediment quantity on the sorption using 1ppm solution. The result shows that the balance adsorption quantity is larger with lower sediment concentration. The balance adsorption quantity decreases with the increasing of sediment quantity and finally reaches a stable state. The reason may be that as sediment quantity increases the adsorption site increases as well gradually and meanwhile, the adsorption changes from multi - molecule layer to a single - molecule layer. As a result, the unit adsorption quantity decreases in a whole.

### **2.6 The effect of different flow velocity on the sorption**

In addition, we also reviewed the effect of different flow velocity flow on the sorption. As a result, with the increase of flow velocity, the balance adsorption quantity tends decreasing gradually. The reason for it may be that the great flow velocity can wash away the organic compound adsorbed on the sediment. This study can provide the references for the organic contamination in different flood periods.

### 3 Conclusions

In this paper, we reviewed the adsorption and the desorption behaviors of Nap and BHT on the sediment from Lanzhou reach of the Yellow River. We also fitted the experimental data of sorption and desorption using three adsorption isotherm equations. The sorption of naphthalene and BHT is characterized by "S" model isotherm curve which can be well described by Freundlich equation. There is hysteresis in the desorption experiment of naphthalene and BHT. These conclusions provide some scientific basis for the study of the transform and transport of organic compound in the muddy river and the study of control for contamination of organic compound.

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## Preliminary Analysis on Pollutant Source and Quantity at Bapanxia Hydropower Station

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**Abstract:** This paper aims at the effects of floating wastes and solid pollutant flowing from tributaries of Huangshui River and Datong River during flood season on the normal operation of Bapanxia hydropower station which is in the mainstream of the Yellow River. Making out the sources, kinds and distribution of pollutant, and then to analyze the relation among source, occurrence time, magnitude of flood and quantity and kinds of pollutant. To qualitative forecast pollutant quantity, then put forward principles of pollutant discharging operation at Bapanxia hydropower station.

**Key words:** Pollutant, Pollutant forecast, Regulation, Bapanxia hydropower station

### 1 Foreword

Bapanxia hydropower station is located in the confines of Lanzhou city of Gansu province in the upper Yellow River, with reservoir capacity of 0.049 billion m<sup>3</sup>, the hydropower station mainly focuses on power generation and multipurpose of such irrigation as well, with total installed power – generating capacity of 180 MW and annual output of generated electricity of 1.1 billion kWh.

Only with daily regulating capacity and not large proportion of installed capacity in the system, but as the lowest – level reservoir in the river reach of Lanzhou, Bapanxia hydropower station plays important role among the cascade reservoirs of Gansu province on the Yellow River. The water regulation in the upper reach is mainly taken by Longyangxia and Liujiaxia reservoirs. There is a tributary of Huangshui River flows into Bapanxia reservoir, frequently with great unexpected rainstorm flood that brings about certain difficulties for reservoir regulation. Huangshui River basin is economically developed area in Qinghai province with concentrated population and developed reclamation, the great deal of pollutant including domestic wastes, ryegrass, branches, sediment and so forth centrally flow with the first flood into the river channel every year, and then carrying into Bapanxia reservoir, which caused jams of trash racks of water – wheel generator set during short time, and threaten to the safe operation of power plant.

For years, with lack of systematic research on moving laws of pollutant in Huangshui River, the regulation of pollutant discharge has been very passive. Seeing from phenomenon, domestic wastes mainly are as floaters moving on the water surface, braches are suspended particles moving within the water. At present, there are no relevant observed items set up in hydrological stations with no means to monitor on them. There are still some problems carrying out for solutions, such as how much flow discharge the pollutant begins to increase, how much the total volume, when the pollutant arrives at the dam, how to proceed regulation in better ways and so on.

The research on pollutant discharge of Bapanxia hydropower station is to study the solid pollutant suspended in the water that influences the operation of power plant based on the actual issues of reservoir regulation. According to this research the moving laws of pollutant in Huangshui River can be understood and mastered basically, and the mode of anti – pollution regulation at power plant correspondingly determined, so as to improve the level of safe operation of Bapanxia hydropower station itself and power grids in Gansu province.



## 2 General Introduction on Huangshui and Datong River Basin

### 2.1 River system upper Bapanxia Reservoir

Bapanxia reservoir is located on the mainstream of the Yellow River with distance of 52 km upper toward Lanzhou, distance of 3,395 km to estuary and drainage area of 215,851 km<sup>2</sup>, Liujiaxia and Yanguoxia reservoirs is located on the upper reach with distance of 50 km and 17km, respectively. Huangshui River flows into the mainstream with distance of 5.1 km to the upper dam.

Shangquan station lies in E103°18', N36°04' with catchment area of 182,800 km<sup>2</sup>, being the inflow station on the mainstream of Bapanxia reservoir, the runoff and sediment being regulated by Yanguoxia and Liujiaxia reservoir, with mean yearly runoff of 27.73 billion m<sup>3</sup> and mean yearly sediment discharge of 0.437 million t, the daily hydrograph shows the variation of double peaks and double valleys.

Both Huangshui River and Datong River are main tributaries of the upper Yellow River. Datong River flows into Huangshui River at Bazhougou with 1km lower Minhe station, and then flows through 74 km at the dam of Bapanxia into the mainstream. The floating pollutant from Huangshui River and Datong River is the key factor for the jam of trash racks of Bapanxia generator set, which directly leads to increase abandoned water of reservoir and influence safety of power plant.

### 2.2 Survey of Huangshui River Basin

Huangshui River is an important tributary on the upper Yellow River. Huangshui River basin lies between E 101° ~ E 103° and N 36.3° ~ N 37.5°, with area of 16,100 km<sup>2</sup> and that upper Minhe control station of 15,300 km<sup>2</sup>, the length of total mainstream is about 300 km and that from Xining to Minhe is 126 km. Its river system distributes in branching – shape and feathery – shape.

The whole basin can be divided into three geomorphic units of medium height mountain, foothills and valleys. Its river source belongs to medium height mountains over 2,750 meters above sea level, with cold weather, higher yearly precipitation, better vegetation and not serious water and soil loess. Foothills occupied about half of total area in the whole basin, 2,000 ~ 2,750 meters above sea level with broken landscape for long – term rains erosion, owing to sparse vegetation, great intensity of rainstorm and serious water and soil loess, is the main sediment – yielding area of Huangshui River. The valleys mainly centralized among mountains in the middle and lower mainstream and main branch gullies with better vegetation, 1,650 ~ 2,500 m above sea level and area occupied 10% of the whole basin, the flat land in platform with gravity irrigation being the basic industrial and agricultural region in Qinghai province.

The precipitation in Huangshui River basin is characterized as uneven time – space distribution, with annual precipitation of 300 ~ 600 mm mainly concentrated in the period from June to September, the annual runoff allocation is identical with precipitation, the runoff during June to October occupied about 70% of yearly runoff, while the interannual variation of runoff standing out that the largest annual runoff is 3 times of the smallest one. All of large floods are formed by rainstorms with character of frequent fluctuation and sometimes occurring mudflows in mountain streams during rainstorm concentrated. The sediment in Huangshui River inner Qinghai province mainly from the lower reach of Xining, especially the foothills area lower Daxia.

### 2.3 Survey of Datong River Basin

Datong River basin lies between E 98.6° ~ E 102.8° and N 36.3° ~ N 38.5° with drainage area of 15,100 km<sup>2</sup> and full length of mainstream of 560.7km, showing feathery shape and narrow strip of topography. According to geomorphic features, Datong River can be divided into three reaches, the upper reach is from the source to Gadatan hydrological station with length of 297.1 km, drainage area of 7,893 km<sup>2</sup> and mean slope of 5.2%, mainly characterized with alpine steppe and marshy area but cold weather. The middle reach is from Gadatan to Liancheng of Gansu province with length of 223.4 km, drainage area of 6,021 km<sup>2</sup> and mean slope of 4.7‰ as well as

good vegetation. The lower reach is the lower toward Liancheng with length of 40.2 km, drainage area of 1,216 km<sup>2</sup> and mean slope of 4.6‰, as well as broken topography and barren hills and waste lands where the main source area of sediment into Datong River.

The annual precipitation in Datong River basin is between 300 ~ 600 mm decreasing from southeast to northwest and mainly concentrated in the period from June to September, the annual mean air temperature between 0.6 ~ 8.3 °C. Annual runoff distributes unevenly but with little interannual variation and identical with precipitation, the runoff from June to September counts for 63% ~ 72% of the whole year. Most of tributaries in Datong River basin originate from south slope of Qilian Mountain, the forest and vegetation plays significant roles on headwater conservation, soil and water conservation, runoff adjustment, water quality purification and improvement of ecological environment. This basin is the area with most slight of water and soil loess in the Yellow River basin, water and sediment centralizing in July and August, great flood mainly from the reach upper Gadatan with slow fluctuation, the sediment mainly from the reach lower Tiantangsi.

## 2.4 The source of pollutant

(1) The pollutant which influenced safe operation of Bapanxia hydropower station mainly from the middle and lower area of Huangshui and Datong River basin, while there is pollutant discharge rarely from the reach between Yanguoxia and Bapanxia on the mainstream, with little threat to safety of Bapanxia power plant.

(2) The pollutant mainly including natural tree and weeds, various plastics of domestic wastes, wove bags abandoned by industrial and agricultural production along river valleys, wastes and beams of building sites, ryegrass and corn stalks piled in the river valleys, etc., among of trees and weeds mainly in the valley floodplain and tributaries of Huangshui and Datong river, domestic wastes distributing in centrally populated city or town, residential communities and banks along tributaries, production wastes concentrate in garbage and building sites along the river valleys.

(3) Carrying with rainstorm and rainstorm flood, pollutants come together into Shuangshui, Datong River and then flowing into Bapanxia reservoir to cause threats on power plant.

(4) For the construction of highways, Huangshui river valleys probably become a main source of wove bags pollutant in future.

## 3 To Draw Up Forecasting Plans on Pollutants

### 3.1 Relations between source and magnitude of flood and quantity and kinds of pollutant

Under ordinary conditions, there are few pollutants carried with middle and small floods, and the kinds of pollutants including domestic wastes, plastics foam, ryegrass, sands, branches, etc., while the pollutants begin to increase in the case of large flood and great flood above 600 m<sup>3</sup>/s, with much more kinds such as trees, branches, wove bags and so forth that constitute threats to safety of power plant, as flow discharge of 1,000 m<sup>3</sup>/s, river flooded and pollutant sources increased, the trees easily swept down.

The floods with different sources carried with different kinds of pollutants. The floods from the upper Huangshui Rive generally carry with pollutants of plastics foam, domestic wastes, wove bags, etc., floods from middle and lower area of Huangshui River always carry with trees, branches and sediment as well as ryegrass piled up in flood land, floods from the upper Datong River basin mainly carry with trees and branches as well as domestic wastes during flood spreading process, the floods from the middle and lower Datong River with large sediment concentration also carry with much more domestic wastes, the floods from uncontrolled area of Minhe and Xiangtang stations (from the lower Minhe and Xiangtang to Bapanxia reservoir) generally with discharge of tens to 500 m<sup>3</sup>/s and flood spreading time of about 3 ~ 6 h mainly carry with domestic wastes, branches and plastics which

constitute great threats to power plant.

For the floods generally from uncontrolled area and the upper Huangshui and Datong River, pollutants come before flood peaks, while for the floods from the middle and lower reach, pollutants always take place on the crest and follow the peaks. This is related with precipitation area and flood composition. Anyhow, the factors that affect pollutant occurring time during flood is rather complicated, with many combined types that need to determine during flood producing process.

As small discharge during non - flood season, the river valleys and flood lands of Huangshui River have become releasing places of domestic wastes, the abandoned things such as agricultural plastic film, corn stalks, ryegrass and so forth piled up in the gullies, river valleys and riversides are crushed into river channel with the first flood every year, so there occurs large quantity of pollutants during first flood each year. According to data statistics in recent over ten years, the first flood of Huangshui River commonly occurs in the end of June or July with flood discharge of above 400 m<sup>3</sup>/s and great quantity of pollutants carried, if the first flood occurs after crop harvest, the pollutants carried with flood will bring about great threats to power plant operation.

In case the second flood smaller than the first one or larger than first one but does not meet flooding standard, the quantity of pollutant will decrease obviously and with trees and sediment as main. If the second flood larger than the first one and meet flooding standard, the quantity of pollutants will increase as well as pollutant kinds, especially the pollutants such as trees, branches and so forth which affect safe operation of reservoir power plant will increase.

### 3.2 Pollutant prediction

As pollutant source is rather complicated, it didn't proceed pollutant monitoring and forecasting work and lack of quantitative data, so this plan can only be regarded as a qualitative prediction that distinguish the quantity and kinds of pollutants carried into Bapanxia reservoir.

**Table 1 Prediction Plan on Pollutant Carried with Inflow Flood into Bapanxia Reservoir**

No.	Flood source	Magnitude of flood(m <sup>3</sup> /s)	Travel time (h)	First flood or not	Quantity of pollutant	Kinds of basic pollutant
1	Upper Daxia of Huangshui River	200 below	10 ~ 15	Y	more	Branch, wastes, sand
				N	less	sand
		200 ~ 600	7 ~ 10	Y	more	wastes, branch, sand
				N	less	sand
		600 ~ 1,000	6 ~ 7	Y	quite more	Tree, wastes, sand
				N	more	Branch, sand
				Y	quite more	Tree, wastes, sand
				N	quite more	Tree, sand
2	Lower Daxia of Huangshui River	200 below	10 ~ 15	Y	more	Sand, branch, wastes
				N	less	Sand
		200 ~ 600	7 ~ 10	Y	quite more	Wastes, branch, sand
				N	more	Sand, branch, wastes
		600 ~ 1,000	6 ~ 7	Y	quite more	Tree, wastes, sand
				N	more	Sand, tree
				Y	quite more	Sand, tree, wastes
				N	more	Tree, sand
1,000 above	5 ~ 6	Y	quite more	Sand, tree, wastes		
		N	more	Tree, sand		

**Table 1**

No.	Flood source	Magnitude of flood( $m^3/s$ )	Travel time (h)	First flood or not	Quantity of pollutant	Kinds of basic pollutant
3	Upper Gadatan of Datong River	200 below	10 ~ 15	Y	less	Wastes
				N	less	
		200 ~ 600	7 ~ 10	Y	more	Wastes, branch
				N	less	
		600 ~ 1,000	6 ~ 7	Y	more	Tree, wastes
				N	quite more	
		1,000 above	5 ~ 6	Y	more	Tree, wastes
				N	more	
4	Lower Gadatan of Datong River	200 below	10 ~ 15	Y	less	Sand, wastes
				N	less	
		200 ~ 600	7 ~ 10	Y	quite more	Wastes, sand
				N	less	
		600 ~ 1,000	6 ~ 7	Y	more	Wastes, sand
				N	less	
		1,000 above	5 ~ 6	Y	quite more	Wastes, sand
				N	more	

## 4 Pollutant – discharging Operation at Bapanxia Reservoir

### 4.1 Operational principle of trash racks

Pollutant cannot pass through the spaces between bars at trash racks, only absorbed on the trash racks with flow action, together with frame and bars of trash racks to constitute pollutant barrier, with continuous pileup of non – deformation things, small or thinly deformation things also blocked on the barriers, when flood carried with large quantity of pollutant, many pollutants blocked making the jams of trash racks rapidly.

The setup of trash racks is to avoid the pollutants that harmful to safe electricity generation into volute housing. The general theory thinks that largest outer size of pollutant allowable into volute housing should be less than 1/2 of space between guide blades or 1/20 of diameter of rotating wheels. Hereby to calculate that the space between bars of trash racks at Bapanxia reservoir should be set less than 26cm. The trash racks itself has no disadvantageous effect on safe electricity generation during actual operation, the key factors to judge the effects of trash racks are as follows, ①to guarantee safe operation of generator set; ②with less head loss; ③stronger pollutant – discharging capacity; ④economical with time and effort on pollutant – removing. It has developed reform to trash racks since 1990 and there are three sets put into operation. On the point of actual effect, new trash racks make certain improvement on four of key factors above mentioned.

### 4.2 Principle of pollutant – discharging regulation

The task of pollutant – discharging regulation is to release pollutants within flood bypassing flood releasing structure as much as possible via water regulation means and thusly to lighten jams of trash racks. The power generating operation should obey requirement of pollutant discharge. The

pollutant – discharging regulation should determine opening means of sluice gate and operational mode of power generator set based on flood forecasting plans and the relation between flood and pollutant. When flood occurs at the same time both in the mainstream and Huangshui, Datong River, it should consider to carry out peak – staggering regulation and reduce abandoned water as possible.

### 4.3 Operational plan of regulating sluice for pollutant discharge

(1) If floats of reservoir meet more or above standard, it should open a plain gate to discharge pollutant, at the same time, reduce flow discharge for power generation, then guide main flow bypass flood releasing sluice gate, and under conditions to meet the needs of power grids and safe operation of power plant, fully open #8 sluice gate.

(2) Plain gate mainly used in pollutant discharge, radial gate used in regulating runoff and sediment. Plain gate chooses # 8 or # 6, radial gate chooses # 9 or combination of # 5 and # 7, but the combination of # 8 and # 9 is a prior recommendation.

(3) The sluice gate should be opened timely, if it is first flood with discharge of more than 600 m<sup>3</sup>/s, the plain gate should be opened before floods arriving at reservoir.

(4) When pressure difference reaches 1.0m and that above, the trash racks should be cleaned timely and then opened the gate to discharge pollutants.

### 4.4 Other remarks

(1) Sediment releasing needs of reservoirs on the mainstream should put into consideration.

(2) As the pressure difference of # 1 and # 5 generator set easily increases in case of flood occurrence, therefore it should consider firstly to reduce loads of # 1 and # 5 generator set when allocating loads.

(3) Pollutant – discharging regulation should be conducted under conditions of power grids balance and flow discharge balance (Table 2).

**Table 2 Operational plan of regulating sluice for pollutant discharge**

No.	Discharge m <sup>3</sup> /s	Quantity of pollutant	Stage control (m)	Opening time of plain gate	Opening of radial gate (#9 or # 5 & # 7 combine)
1	<200	quite more	1,577.00 above		
		less	1,576.50 ~ 1,577.00	1 ~ 1.5	#9/ plain gate corresponding
2	200 ~ 600	quite more	1,576.50 ~ 1,577.00	0.5 ~ 1	Regulate spare flow
		less	1,576.50 ~ 1,577.00	1 ~ 1.5	Regulate spare flow
3	600 ~ 1,000	quite more	1,577.00 above		
		less	1,576.30 ~ 1,576.80	1 ~ 2	#9/ plain gate corresponding
		quite more	1,576.30 ~ 1,576.80	0.5 ~ 1	Regulate spare flow
		less	1,576.30 ~ 1,576.80	0.5 ~ 1	Regulate spare flow
4	>1,000	quite more	1,576.30 ~ 1,576.80	1 ~ 2	#9/plain gate corresponding
		more	1,576.30 ~ 1,576.80	1 ~ 1.5	Regulate spare flow
		quite more	1,576.30 ~ 1,576.80	1 ~ 2	Regulate spare flow
		more	1,576.30 ~ 1,576.80	1 ~ 1.5	Regulate spare flow

## 5 Conclusions

According to this survey on floats sources in the area upper Bapanxia reservoir, to analyze laws of flood and sediment in Huangshui and Datong River, draw up forecasting plans on flood, sediment and pollutants, study regulating plans and countermeasures of pollutant release and then form the basic knowledge and conclusions as follows,

(1) Pollutants that influenced normal operation of Bapanxia reservoir mainly from Huangshui and Datong River basin, the wastes in the area between Yanguoxia and Bapanxia on the mainstream cannot constitute the threat to safety of Bapanxia power plant.

(2) Since 1990, each flood carried with great number of pollutants and increased year by year, trees, industrial products and domestic wastes count for major pollutants, it's related closely with ecological protection and city pollution in Huangshui River basin. With sparse vegetation, broken landform and different source of water and sediment, the middle and lower area of Huangshui and Datong River which concentrated population with industrial and agricultural production is the basic source area of plastics foam, wove bags, domestic wastes and sediment.

(3) Flood is a carrier of pollutants, the first flood in every flood season carries with pollutants of domestic wastes, etc. gathered in the river channel during non - flood season arriving at the dam, the rainstorm flood occurred in the middle and lower area will crush branches, trees and domestic wastes into river channel, the overbank floods crush weeds, trees, branches and domestic wastes piled up during non - flood season on the floodplain and riversides into river channel.

(4) The first flood every year with discharge over  $600 \text{ m}^3/\text{s}$  will wash out extensively the whole river channel, ordinarily called wash channel. Such floods certainly carry with almost pollutants piled up on the riverbed since non - flood season, with increment of flow magnitude, the extent of harm would be aggravated correspondingly.

(5) Pollutants mainly concentrated in the initial phase of flood occurrence, time - space distribution of pollutants in the river channel is earlier than attenuation of flood peaks, so as to master the characteristics of pollutant time - space distribution is the key to achieve success on pollutant - discharging regulation. With complicated characteristics of natural environment, rainstorm flood and pollutant in Huangshui and Datong River basin, as well as the development of industrial and agricultural production and human activities which caused the changes of pollutant source and constituents, it will display certain functions to guide and improve pollutant - resisting regulation at Bapanxia reservoir.

(6) Pollutant control at Bapanxia reservoir adopted with non - structural measures and engineering measures. Non - structural measures include, pollutant - resisting regulation at reservoirs is a brandnew topic to study, in past times, there has no any experience on monitoring and forecasting of floating pollutants in the rivers, immediately following this in time to proceed this work and provide basis for Bapanxia reservoir regulation, meanwhile to establish hydro - meteorological integrated flood forecasting system in the non - controlled area from Minhe, Xiangtang to Bapanxia, as a result to predict quantity and arriving time at reservoir of pollutants produced by rainstorm in the non - controlled area. In addition, according to intensify publicity and education and strengthen river basin management, thus to reduce the quantity of man - made pollutants such as abandoned wastes of building sites and so forth.

Engineering measures include Yanguoxia reservoir on the mainstream of the Yellow River, small power plant constructed at Daxia in Huangshui River, intakes hinge of water diversion project from Datong River to Qinwangchuan near Tiantangsi and also small power plant at Xiangtangxia in Datong River, therefore part of floating pollutants can be headed off firstly on the Huangshui and Datong rivers, it is operational to set up pollutant - blocking project at the entry of Huangshui river flowing into reservoir and hold the floating pollutants outer the reservoirs, thus to reduce the threat of pollutants to the safety of power plant.

## Analysis on Water Quality of Lower Yellow River since Integrated Water Dispatching

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**Abstract:** In order to understand water quality situation in the lower Yellow River since the integrated dispatching of water quantity of the Yellow River, the current water quality situation there was analyzed according to the water quality monitoring data in 2006, and the water quality change tendency of five sections during 1999 ~ 2006 was statistics analyzed by using Daniel tendency inspection method. The results indicated that current water quality is good in the lower Yellow River, the water quality in flood season is better than that in non – flood season, the water quality of the lower reaches has gradually turned better since 1999, which is closely related to the effort of the water resources protection management department and the increase of water volume because of the integrated dispatching of water quantity of the Yellow River. However, sewage discharging and entering into the Lower Yellow River still take on the increasing tendency, so the water resources protection for the Yellow River is an arduous task to be carried out in the future.

**Key words:** the Lower Yellow River, water quality, change tendency

### 1 Survey of the Lower Yellow River

The main stream of the Yellow River below Taohuayu is designated as the lower reaches, with a length of 786 km, where the river bed is generally higher than the ground outside both banks, and the joining branches are only a few, they are Tianranwenyanqu, Jindi and Dawen rivers. The river reach from Taohuayu to Gaocun measures 206.5 km in length, as a wandering section, it scours and silts fiercely, with wide, shallow, disperses and chaotic flow. The section from Gaocun to Aishan extends 193.6 km, and is the transition section, and Aishan to Lijin section of 281.9 km is the meandering reach which the river direction is more regular and stable.

The Yellow River provides the rich fresh water resources to the industrial and agricultural production, the living and ecological environment water used in the delta area, about 95% of the total water resources demanded by the river estuarial area relies on the Yellow River to supply. Therefore, water resources of the Yellow River is an important safeguard for sustainable development of social economy and ecological environment in the Yellow River delta area, whether water quality is good or not, directly affect water used security of the river mouth delta area.

In order to understand water quality situation of the Lower Yellow River, the five representative sections which is Huayuankou, Gaocun, Aishan, luokou and lijin have chosen to analyze its present water quality situation and the change tendency in the lower Yellow River. Huayuankou is the first section for the downstream where water quality is surveyed, and also is the important controlling section which is the junction of the Yellow River water between Henan and Shandong. Gaocun is the upstream controlled section where the Yellow River water runs into the boundary of Shandong province. Aishan is the controlled cross section of water quality after Jindi River and Dawen River join the Yellow River. Luokou is the controlled section for Jinan suburbs and Lijin is the controlled section entering the sea.

### 2 Analysis of water quality present situation

According to water quality monitoring results of the lower Yellow River in 2006, on the basis of

“Environmental Quality Standards for Surface Water” (GB 3838—2002), 18 monitoring parameters were chosen, that is water temperature, pH, dissolve oxygen, permanganate index, chemical oxygen demand, biochemical oxygen demand for five days, ammonia nitrogen, cyanide, arsenic, volatility phenol, chromium VI, chromium, fluoride, mercury, cadmium, plumbum, copper, zinc and petroleum, by using the single factor appraisal method to evaluate water quality of five sections in the lower Yellow River, which is Huayuankou, Gaocun, Aishan, Luokou and Lijin. The evaluation results see Table 1.

**Table 1 Evaluation results of water quality in the Lower Yellow River**

Section	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Year
Huayuankou	III	IV	IV	IV	III	III	III	III	III	III	III	III	III
Gaocun	III	V	V	IV	III	III	III	III	III	III	IV	IV	III
Aishan	III	IV	IV	III	III	III	III	III	III	III	III	V	III
Luokou	III	IV	III	III	III	III	III	III	III	III	III	IV	III
Lijin	III	IV	III	III	III	IV	III	III	III	III	III	III	III
Meeting III category (%)	100	0	40	60	100	80	100	100	100	100	80	40	100
Meeting IV category (%)	0	80	40	40	0	20	0	0	0	0	20	40	
Meeting V category (%)	0	20	20	0	0	0	0	0	0	0	0	20	

According to the water quality evaluation results in 2006, water quality of the whole year is good in the Lower Yellow River, water quality of the whole year in five sections are all III category of water quality standard. Water quality are good in January, May, July, August, September and October of the whole year, that all reaches III category; the water quality ranks the second in June, and November, III category of water quality sections account for 80%, and IV category of water quality sections account for 20%; water quality in February is the worst, water quality of five sections all exceed III category of standard, IV category of water quality section accounts for 80%, V kind of water quality sections accounts for 20%. In a whole, water quality of the flood season is better than the non - flood season, which is possibly related to water volume of the flood season bigger than that in non - flood season.

**Table 2 The parameters exceeding the standard of the downstream section in 2006**

section	The parameter exceeding the standard					
	Feb	Mar	Apr	Jun	Nov	Dec
Huayuankou	Ammonia nitrogen	Ammonia nitrogen	Ammonia nitrogen			
Gaocun	Ammonia nitrog	Enammonia nitrogen	COD <sub>Cr</sub>		Petroleum	Petroleum
Aishan	Ammonia nitrogen	Ammonia nitrogen				COD <sub>Cr</sub> , BOD <sub>5</sub> , volatility phenol, petroleum
Luokou	Ammonia nitrogen					Petroleum
Lijin	Ammonia nitrogen			BOD <sub>5</sub>		

According to the statistics of 2006, ammonia nitrogen, chemical oxygen demand, biochemical



oxygen demand for five days, petroleum, volatility phenol are the main pollutant of the lower Yellow River.

### 3 Water quality change trend analysis

Since the integrated dispatching of water quantity of the Yellow River in 1999, it has realized the striking achievement which the Yellow River has not dry off in the continuous seven years through integrated water resources dispatching and scientific collocating. Through integrated water resources dispatching management, the water used by ecological environment was increased, which obviously improved ecological environment, realized the harmonious relation between human and water, and promoted social economy and ecological environment sustainable development in the river mouth delta area.

The water quality data for eight years from 1999 ~ 2006 have been selected in this article, to analyze the change tendency of water quality in the Lower Yellow River. The change tendency of main pollutant such as chemical oxygen demand, ammonia nitrogen, permanganate index, biochemical oxygen demand for five days in Huayuankou and Lijin sections from 1999 ~ 2006 see Fig. 1 ~ Fig. 4.

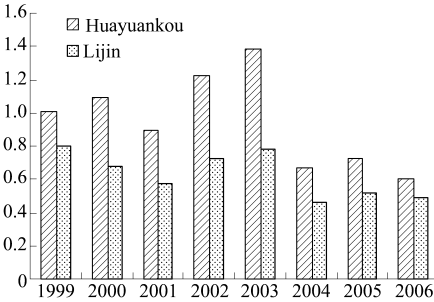


Fig. 1 The change trend of ammonia

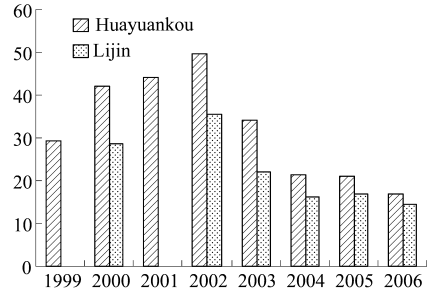


Fig. 2 The change trend of COD<sub>Cr</sub>

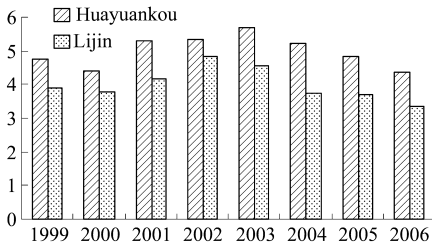


Fig. 3 The change trend of permanganate index

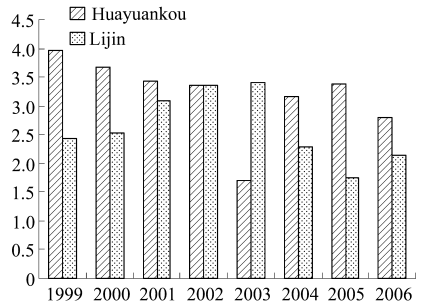


Fig. 4 The change trend of BOD<sub>5</sub>

Because of the affect from many factors, water quality monitoring results often display the fluctuating characteristic, for monitoring value trends to rise sometimes, but trends to drop sometimes, it is very difficult to determine the entire change tendency of the pollution, so the quantitative analysis of change tendency for water quality must depend on statistics principle to exam the tendency.

This article use Daniel tendency verifying method in the statistic to verify water quality change tendency remarkable or not. This method uses the spearman's order relative coefficient, which requires sample numbers are bigger than four. It is suitable to the correlation examination of single factor and small sample number. This method is simple and highly precise.

Supposing there is a group of monitoring time sequences, they are  $Y_1, Y_2, \dots, Y_n$  and corresponding concentration values  $C$  (namely average value  $C_1, C_2, \dots, C_n$ ), according to the concentration value, produce their serial numbers from small to big  $X_i$ , the sequence of monitoring value is called the order of the monitoring value. Then, the order's relative coefficient of this group of value can be calculated through the following formula.

$$r_s = 1 - 6 \sum_{i=1}^N d_i^2 / (N^3 - N)$$

$$d_i = X_i - Y_i$$

In the formula:  $d_i$  is the difference between variable  $X_i$  and  $Y_i$ ,  $X_i$  is the serial number of period  $N$  which is arranged from small to big according to the concentration value,  $Y_i$  is the serial number arranged by time,  $N$  is year.

The absolute value of order relative coefficient was compared with its critical value in statistical table. If the absolute value of order relative coefficient is bigger than its critical value, it indicated the change tendency has the remarkable significance. If the absolute value of order relative coefficient is a negative value, it indicated the trend is dropping; otherwise, the trend is rising.

According to the water quality monitoring data of five sections (namely, Huayuankou, Gaocun, Aishan, Luokou and Lijin) in the lower Yellow River during 1999 ~ 2006, the annual mean value of the main pollutant such as chemical oxygen demand, permanganate index, ammonia nitrogen, biochemical oxygen demand for five days, volatility phenol were selected, the Daniel tendency verifying method was used to count the change tendency of every main pollutant, the computed results of order relative coefficient see Table 3, and when  $n=6, r_{0.05}=0.886; n=7, r_{0.05}=0.786; n=8, r_{0.05}=0.738$ , the statistic result of change tendency for main pollutants see Table 4.

**Table 3 The order relative coefficient of the main pollution in the Lower Yellow River during 1999 ~ 2006**

Section	COD <sub>Cr</sub>	Ammonia nitrogen	Permanganate index	biochemical oxygen demand for five days	Volatility phenol
Huayuankou	-0.667 ( $n=8$ )	-0.571	-0.071	-0.762	-0.417
Gaocun	-0.857 ( $n=7$ )	-0.762	-0.595	-0.595	0.202
Ai' shan	-0.714 ( $n=6$ )	-0.667	-0.571	-0.405	-0.262
Luokou	-0.857 ( $n=7$ )	-0.786	-0.405	-0.595	-0.440
Lijin	-0.886 ( $n=6$ )	-0.714	-0.571	-0.5	-0.536

**Table 4 The statistical result of the main pollution change trend in the Lower Yellow River during 1999 ~ 2006**

Section	COD <sub>Cr</sub>	Ammonia nitrogen	Permanganate index	Biochemical oxygen demand for five days	Volatility phenol
Huayuankou	Drop	Drop	Drop	Remarkable Drop	Drop
Gaocun	Remarkable Drop	Remarkable drop	Drop	Drop	Keep stable
Ai' shan	Drop	Drop	Drop	Drop	Drop
Luokou	Remarkable drop	Remarkable drop	Drop	Drop	Drop
Lijin	Remarkable drop	Drop	Drop	Drop	Drop

According to the counted results, besides the concentration change of volatility phenol keeping stable in Gaocun section, the change trend of other pollution drop in various sections. The concentration change of biochemical oxygen demand in Huayuankou, and ammonia nitrogen in Gaocun and Luokou remarkably drop. The results indicated that water quality has gradually changed

to the better in the lower Yellow River since the integrated dispatching of water quantity of the Yellow River in 1999, on the one hand, it is relative to the endeavor of water resources protection management department, on the other hand, it is closely relative to scientific dispatching and reasonable collocating of water volume of the Yellow River.

Table 5 displayed annual runoff change of Huayuankou, Gaocun and Lijin sections in the lower Yellow River during 2000 ~ 2005. From the Table, we can see the annual runoff of Huayuankou, Gaocun and Lijin sections are increasing year by year, especially in Lijin section, the water volume has a bigger increase from 2003. The integrated dispatching of water quantity of the Yellow River made the basic runoff guaranteed in the lower reach. The increasing water volume dilutes the pollution concentration in water body on some degree. Water quality has changed for better. But it is not the ultimate method to solve water pollution by merely relying on increasing the water volume.

**Table 5 The annual runoff in the lower Yellow River during 2000 ~ 2005**

Section	Unit: billion m <sup>3</sup>		
	2000	2003	2005
Huayuankou	165.3	272.7	257.0
Gaocun	136.9	257.6	243.4
Lijin	48.59	192.6	206.8

#### 4 Sewage discharge situation

Table 6 displayed the discharged sewage in the Lower Yellow River during 2000 ~ 2005. From the Table 6, we can see discharged quantity of the industrial waste in the lower Yellow River is reducing year by year, the discharged quantity of the living waste is increasing year by year, the total discharged waste appear the increasing tendency year by year, the sewage entering the river in the lower Yellow River also increase year by year. Because there are many densely populated cities located along both banks, with the urban population increasing, the living discharged sewage had a bigger increase from 17.4% in 2000 to 56.1% in 2005. The discharged industry sewage had reduced from 82.6% in 2000 to 33.3% in 2005.

**Table 6 Waste discharged volume in the lower Yellow River during 2000 ~ 2005**

Year	Waste discharged volume					Waste entering the river
	Total	Industry	%	Living	%	
2000	2.87	2.37	82.6	0.5	17.4	
2003	3.05	0.95	31.1	1.82	59.7	1.25
2005	3.12	1.04	33.3	1.75	56.1	1.86

#### 5 Conclusions

Since the integrated dispatching of water quantity of the Yellow River has been implemented, because of scientific dispatching and reasonable collocating of water resources, the basic current of downstream course basically has been guaranteed in the dry season, the phenomena of drying off basically has been controlled, water quality has changed for the better. But the sewage discharged and entering into the river appear the increasing trend year by year in the lower reaches, because the efficiency of city sewage treatment is very low in the Yellow River, the majority of pollution sources were difficult to realize the aim which stably reach the standard to discharge, the phenomenon stealing to discharge and exceeding the standard to discharge still exist. With the

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economical development and the increasing population, the discharged sewage and the pollutant entering into river will further enlarge in the future, the water pollution aggravated will be not inevitable under the natural coming water volume of Yellow River the same or even reducing, Therefore, it can not merely rely on increasing the runoff to dilute the pollutant concentration so as to improve water resources quality of the Yellow River, pollution preventing and controlling shall be reinforced, and the pollutant entering into the river shall be reduced in order to improve ultimately the downstream water quality, protect water resources of the Yellow River, promote the coordinated development of water resources, social economy and ecological environment in the river mouth area, and maintain the healthy life of the Yellow River.

# Preliminary Study on Strengthening Ecological Construction and Improving Water Quality of Gudong Reservoir

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**Abstract:** The factors impacting the water quality of the Gudong Reservoir, the plain reservoir in the Yellow River estuary, have been discussed in the paper. After having identified the factors and described their impact principle, a proposal on how to improve the reservoir water quality and how to build an ecosystem was put forward. In recent years the water quality indicators have confirmed the effectiveness of improving the water quality measures for the Gudong Reservoir.

**Key words:** plain reservoir, eutrophication, water quality impact factors, reservoir ecological construction, water quality improvement

## 1 Introduction

Shengli Oilfield, located in the Yellow River delta plain, along both banks of the Yellow River, and beside the coast of the Bohai Sea, is poor in natural conditions. The Yellow River water is the only source for water supply to the oilfield. To meet the water demand of the oilfield development and the production of local residents living at the Shengli Oilfield in the Yellow River delta plain, plain reservoirs were built up gradually, with a total capacity of 450 million m<sup>3</sup>, one of which is the Gudong Reservoir that sits about 6 km south of Xianhe township, Hekou District, Dongying City. In recent years, because of the unceasingly discharging of industrial wastewater and domestic sewage, the Yellow River water quality has declined year by year, with a high content of nutrients, resulting in a trend of eutrophication of the plain reservoirs in the Yellow River Mouth, including the Gudong Reservoir, which lead to propagation of a lot of float grass and algae in the reservoirs, further deteriorating the water quality. That has seriously impacted on the physical health of the people in the Shengli Oilfield and Dongying City, and increased the cost for water treatment. Thus, the improvement of the reservoirs water quality in the Yellow River delta to protect the local peoples' health has become a very urgent task. In recent years, the Gudong Reservoir has made a meaningful attempt in strengthening environmental management, and using eco - conservation techniques to raise the water quality of the reservoirs.

## 2 Gudong Reservoir water quality regime

The water quality testing data for the Gudong Reservoir since 2003 were statistics collected, from which five indicators that could mostly represent the extent of eutrophication were selected, i. e. ammonia nitrogen, total phosphorus, total nitrogen, permanganate index and chloride for analyses. The contrast curve shows the reduction of the five indicators to varying degrees from 2003 to the present, indicating the eutrophication of the reservoir water level is gradually declined and water quality must be somewhat improved, and verifying initial achievements in creating an ecological water reservoir of Gudong.

The water quality change law and some information of recent years show the major factors affecting the water quality of the reservoirs are: the Yellow River water diverted, whether the biological chain structure of the reservoir itself is reasonable, environmental treatment, seasonal temperature changes, the fluctuations in water depth of the reservoir.

**Table 1 2003 ~ 2006 Gudong water quality indicator ammonia**

Month	2003	2004	2005	2006	Standard values
Jan	0.21	0.21	0.28	0.62	1
Feb	0.13	0.45		0.26	1
Mar	0.48	0.32	0.49	0.29	1
Apr	0.17	0.57	0.47		1
May	0.12	0.41	0.60	0.15	1
Jun	0.25	0.18	0.64	0.11	1
Jul	0.10	0.18	0.50	0.26	1
Aug	0.05	0.45	0.66	0.52	1
Oct	0.49	0.41	0.30		1
Nov	0.62	0.35	0.52		1
Dec	0.30	0.08	0.46		1

**Table 2 2003 ~ 2006 Gudong water quality indicators TP**

Month	2003	2004	2005	2006	Standard values
Jan	0.03	0.01	<0.01	0.01	0.05
Feb	0.24	0.01		0.02	0.05
Mar	0.10	0.02	<0.01	0.06	0.05
Apr	0.07	0.04	<0.05		0.05
May	0.04	0.02	0.02	0.02	0.05
Jun	0.03	0.01	0.02	0.05	0.05
Jul	0.02	0.01	0.02	0.02	0.05
Aug	0.04	0.02	0.02	0.02	0.05
Oct	0.05	0.41	0.03		0.05
Nov	0.05	0.03	0.03		0.05
Dec	0.02	0.02	0.02		0.05

**Table 3 2003 ~ 2006 Gudong water quality indexes TN**

Month	2003	2004	2005	2006	Standard values
Jan			1.26	0.86	1
Feb				1.71	1
Mar		3.06	2.48	1.44	1
Apr	0.37	3.72	2.20		1
May	3.32	3.08	1.60	2.05	1
Jun	2.01	2.19	2.22	1.89	1
Jul	1.18	1.46	2.77	1.56	1
Aug	5.84	2.51	1.40	1.10	1
Oct	0.88	3.13	2.26		1
Nov	0.62	2.89	1.06		1
Dec	1.90	3.64	1.10		1

**Table 4 2003 ~ 2006 Gudong reservoir water permanganate index detected**

Month	2003	2004	2005	2006	Standard values
Jan	2.32	4.67	2.20	3.97	6
Feb	2.99	2.90	2.39	3.98	6
Mar	2.32	4.00	3.47	3.04	6
Apr	3.07	4.10	3.68		6
May	4.61	5.47	3.88	3.37	6
Jun	4.65	5.79	4.76	3.00	6
Jul	4.78	4.62	4.77	4.09	6
Aug	5.09	4.54	3.66	3.18	6
Oct	4.14	4.22	4.26		6
Nov	4.62	5.12	4.62		6
Dec	4.40	4.18	3.77		6

**Table 5 2003 ~ 2006 Gudong reservoir water laced indexes**

Month	2003	2004	2005	2006	Standard values
Jan	195	273	221	231	250
Feb	98	246		223	250
Mar	171	246	230	222	250
Apr	191	264	221		250
May	227	170	237	155	250
Jun	225	225	202	154	250
Jul	203	223	210	162	250
Aug	198	211	181	161	250
Oct	206	216	202		250
Nov	210	209	206		250
Dec	204	215	206		250

### 3 Water quality impact analysis

#### 3.1 Water structure of biological chain

The main principle of ecological restoration is to achieve water quality improvement by nutrient pollutants in the water ecosystem, constantly flowing along the food chain, and adhered to various kinds of higher aquatic animals that are caught and left the water body. For the main water reservoir ecosystem, a basic structure of the food chain, after years of natural selection and artificial fish fry, has been established, such as plankton, pastures, benthic organisms, fish already existed, but the components of the ecosystem is not perfect, mainly manifested by the inadequate diversity of aquatic organisms (senior aquatic organisms) and unreasonable number of aquatic organisms, so that nutrients can not rapidly go ashore.

#### 3.2 Environment of the reservoir area

The vegetation covered the reservoir area can stop sandstorms, prevent from soil erosion, and absorb soil nutrients. For example, reed is able to remove phosphorus by 65%. As the vegetation

coverage rate there is quite low, that can not protect the water quality, increase workload for maintenance as well, as a result, an increase of man – made pollution.

### 3.3 Season

Potamogeton crispus is growing vigorously from the beginning of March to the end of May. Due to the rising of temperature, growth of potamogeton crispus biomass reaches its peak, at the same time, most decomposed plant causes a large number of algae reproduction. Meanwhile, algae composition and size changes with seasons, temperature and illumination. Diatoms dominates in March, cyanobacteria is superior from May and reaches the maximum from July through October sometimes. Potamogeton crispus, a large number of species breeding will lead to the death of phosphorus and other nutrients to increase the concentration of pollutants, resulting in deterioration of water quality.

### 3.4 Water depth

In shallow water, phytoplankton photosynthesis prompts a large number of aquatic algae blooming, the impact of the wind, benthic animals stirring prompts sediment nutrients to release to the water, resulting in increase of nutrient pollutants in water content.

## 4 The specific measures of reservoir ecosystem construction

### 4.1 Establishment and improvement of water biological chain to achieve self – purification of water

A sound, reasonable and efficient food system shall be established in the water body of reservoirs to create more channels for nutrients to the shore. At the end of May 2002, a large number of floating reeds deaths occurred in Gudong, prompting further large algae blooms, causing deterioration of the water quality. In June 2002, the Water Source team, with the help of Laiyang Agricultural Research Institute, carried out water body research. On the basis of investigation and analyses of water nutrients, organic matter, water organisms (reeds, algae, plankton), they put grass carp (volume control weeds in a reasonable extent) of 4,000 kg, injected 9.1% bighead (mainly to reduce water plankton bottom) of the 2,000 kg. After a year of research, through further water right nutrients, organic matter, water organisms (reeds, algae, Plankton) were investigated on the basis of 2003 spent a total 2,000 kg of grass carp, silver carp put, bighead the 2,000 kg. In 2004 and 2005, after reviewing and analyzing the past experience, on the basis of increasing water surveys, with the aid of the Science and Technology Center of Water Supply Company, the team knew clear about water nutrients and organic matter content, master aquatic organisms (reeds, algae, plankton) and the status of the law, precisely put the number of species, to establish a body of water biological chain so that a target of self – purification of water body was achieved. There are plans to put in herbivorous fish, such as grass carp and Wuchang fish; put in filter – feeding fish, such as the silver carp, bighead stability of the plankton community structure, through which light and nutrients competing inhibit the growth of weeds. In 2006, on the basis of further study on the water body, grass carp and silver carp of 2,000 kg each, and 10 million shrimps were bred, an increase of higher aquatic organisms in terms of type and quantity, to establish a biological chain of water body. A target of self – purification of water body was achieved.

### 4.2 Enforce reservoir environment management

In recent years, considering the sandstorm feature of the coastal region, 120,000 trees have been planted in the ecological forest in both northern and southern reservoir area, 100 acres of alfalfa have been planted in the downstream floodplain of the North dam of the reservoir, sod



cultivation and conservation on its dry slopes have increased, currently turf coverage rate reaching 98%. Reeds around the reservoir have been conserved, seepage intercepting grooves excavated, closed – end management implemented to prevent foreign personnel and vehicles entering. Currently, the scenery of the blue sky, green water, grass – green blossom, all bird flocks, can be seen in Gudong Reservoir, reaching a natural harmony between people and animals.

#### **4.3 Make a good plan for reservoir water level operation**

To work out a good reservoir operation plan, according to the impact factors of season and temperature on the structure of biological chain, timely contact with the higher authorities, the reservoir will store water in spring to raise water level, reduce light, and maximize inhibition of the large population of aquatic plants.

### **5 Conclusions**

With regard to the analyses on detection of water quality indicators of the Gudong Reservoir in the years of 2003 ~ 2006, the construction of ecological water and water quality improvement measures adopted are effective. Currently, the reservoir ecological construction is under the phase of exploration and exploration. For different seasons, water quality and water level situations, there are no any quantitative data available for the deployment and control of biomes structure in the reservoir, which needs to be established by joint efforts of scientific research institutions concerned. In short, the use of biological – ecological restoration technology to raise the self – purification ability of a water body is the development direction of water environment improvement and water quality improvement and is a long – term and persistent work too.