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

Volume Ⅴ

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

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

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 Wanjiazhai 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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Regional Water Resources Allocation and Interbasin Water Transfer

Primary Study on Regulation of Environmental Flow in the Yellow River Estuary

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Abstract: The Yellow River Delta wetland is the youngest, widest, intactest and biggest wetland in China temperate zone. In 1992, the National Nature Reserve was set up. In 1980s and 1990s, the lower Yellow River dried up frequently and the Yellow River estuary ecosystem, whose main water source is Yellow River water, was destroyed seriously. The wetland area shrank and the species and amount of the biology were reduced obviously. Since 1999, after implementation of integrated water regulation of the Yellow River, fresh water resources flow into the estuary area constantly, and it has been no drying up for continuous 7 years, as a result, the fresh water level is rising; the water amount flowing into the sea is increased in planning from March to June, when the biology growth and propagation are in bloom. In addition, continuous 5 years' regulation of water and sediment since 2002, large amount of fresh water flowed into the dried wetland nearby the estuary, and a large amount of sediment were transported into the sea, as a result, the situation of sea water intrusion and land erosion are contained effectively and the wetland area was restored gradually. However, it still exist some problems in water regulation such as water for ecological use is occupied by productive use. In the future, the regulation of the environmental flow of the Yellow River should be intensified by carrying out the "Byelaw of Yellow River Water Regulation".

Key words: the Yellow River, Delta, environmental flow, regulation

1 General situation of wetland and biology in the Yellow River estuary

The wetland of Yellow River Delta is the youngest, widest, intactest and biggest wetland in China temperate zone. In 1992, the National Nature Reserve was set up. This piece of new land was completely created by the sediment flowing into the sea. About 50 years ago, the site of the present nature reserve was sea area. Because of high content of silt in the Lower Yellow River, more than 1 billion t of sediment was transported to the estuary every year, then forming the wetland of Yellow River Delta. The nature reserve is located in the new silted land beside the Yellow River estuary, the total area is 153 thousand ha, in which the core area is 58 thousand ha, buffer area is 13 thousand ha, and pilot area is 82 thousand ha. This reserve is an important "transfer station, winter habitat and breeding zone" for the wild birds migrating between inland of northeast Asia Continent and around West Atlantic Ocean. The main wetland types are shrubbery wetland, meadow wetland, marsh, river wetland and littoral wetland. It is a representative example of estuary wetland ecosystem in the world with 1,524 kinds of wild animals, 283 kinds of birds, 159 kinds of fishes, 394 kinds of plants, 32,772 ha of nature reed, 18,143 ha of meadow, 675 ha of mangrove, 8,126 ha of salix integra Thunb and 5,603 ha of artificial acacia.

2 No – flow conditions of the Yellow River and the harm to the estuary ecology

2.1 No – flow conditions of the Yellow River

The Yellow River is the important water sources for northwest and north part of China. Its total amount of runoff that accounting for only 2% of total amount of water resource of all Chinese rivers is undertaking a great task of supplying water for 12% of Chinese population, 15% of Chinese farmlands and 50 big and medium cities, and supporting 9% of Chinese GDP. It is the foundation and guarantee for sustainable socioeconomic development in the basin and regions concerned.

Since 1970s, with the increase of water demand alongside the Yellow River, the contradiction between supply and demand of the Yellow River water becomes more and more outstanding, and due to the excess and orderless water consumption, the lower Yellow River dried up frequently in transition between spring and summer every year. The interception conditions of the lower Yellow River of years is shown in Table 1.

Table 1 Recorded No – flow conditions of the Lower Yellow River in year

Year	Interception date		Interception times	Interception days		
	Earliest	Latest		Whole day	Interim	Total
1972	4.23	6.29	3	15	4	19
1974	5.14	7.11	2	18	2	20
1975	5.31	6.27	2	11	2	13
1976	5.18	5.25	1	6	2	8
1979	5.27	7.9	2	19	2	21
1980	5.14	8.24	3	4	4	8
1981	5.17	6.29	5	26	10	36
1982	6.8	6.17	1	8	2	10
1983	6.26	6.3	1	3	2	5
1987	10.1	10.17	2	14	3	17
1988	6.27	7.1	2	3	2	5
1989	4.4	7.14	3	19	5	24
1991	5.15	6.1	2	13	3	16
1992	3.16	8.1	5	73	10	83
1993	2.13	10.12	5	49	11	60
1994	4.3	10.16	4	66	8	74
1995	3.4	7.23	3	117	5	122
1996	2.14	12.18	6	124	12	136
1997	2.7	12.31	13	202	24	226
1998	1.1	12.8	16	113	29	142
1999	2.6	8.11	4	36	6	42

As shown in Table 1, after the first no – flow occurred in 1972, the situation got worse gradually. Especially after 1990s, the no – flow of Yellow River happened nearly every year, and the duration time was extending. From 1995 to 1998, the no flow time was more than 100 days every year. In 1997 the condition was the worst, the no flow time in Lijin hydrological station which is the nearest to the estuary was up to 226 days and the no flow channel extended to Kaifeng in Henan Province; the total length of no – flow channel is up to 704 km, accounting for 90% of the Lower Yellow River.

2.2 Harm to the estuary ecology by no – flow of the river

Frequent no – flow of the Yellow River has seriously damaged the estuary ecology.

2.2.1 Decrease of wetlands area

On the one hand, frequent of no – flow of the river, sharp decrease of water volume and silt deposition in the channel led to less sediment flowing to the estuary, increasing of sea water intrusion and land erosion, and caused Yellow Rivr Delta wetland stopping expanding and even shrinking. On the other hand, massive freshwater wetland dried up and disappeared due to long term lack of water. In 1997 the no – flow situation was the worst and 7,000 ~ 8,000 mu of wetland was shrunk. In 1990s, due to sea water erosion and lack of freshwater, the Yellow River Delta wetland shrank to half.

2.2.2 Salinization of land, unbalance of ecology and decrease of biodiversity

On the one hand, frequent of no – flow of the river, long – term no fresh water entering the estuary and Bohai Sea led to drop of the fresh water level, sea water intrusion and land salinization, deterioration of water quality, serious unbalance of ecosystem, dying of biology and vegetation in huge area and decline of fish and bird species. On the other hand, because of wetland shrinking, some animals and plants which live relying on wetland decreased also. According to the statistics, in 1990s, due to serious no – flow of the river, the area of vegetation in estuary area decreased half; fish species decreased 40% ; bird species decreased 30% and some rare biology such as Yellow River saury and east prawn have been extinct.

3 The change of water quantity at Lijin after integrated regulation of the Yellow River water resources

The more and more serious no – flow situation of the Yellow River attracted high attention from the central government and the whole society. In 1997, the State Council and relevant ministries invited some experts and held two forums about the no – flow problem of Yellow River in order to seek some countermeasures.

In order to alleviate the contradiction between supply and demand of the Yellow River water resources and the severe situation of frequent no – flow problem in Lower Yellow River, authorized by the State Council, the National Planning Committee, Ministry of Water Resources issued "Managing Rules of Yellow River Water Resources Regulation" in 1998, and the Yellow RiverCC was authorized to regulate the Yellow River water resources. In order to carry out this job well, the Yellow RiverCC set up the Department of Water Resources Management and Regulation in 1999, which began to carry out integrated regulation of Yellow River water resources in 1999 ~ 2000. The regulation year is hydrological year, i. e. from July to next June and the regulation period is non – flood season, i. e. from November to next June. Since the first execution of integrated water resources regulation of the Yellow River, it has achieved continuous 7 years no flow – break from 2000 to 2006 through careful organization, elaborate regulation and scientific management.

Considering the natural runoff is according to calendar year, namely from 1st of January to 31st of December, in this paper the year of 2000 is the boundary year when analyzing the variation of the runoff quantity at Lijin before and after integrated regulation of the Yellow River water resources, namely from 2000 to 2006 is the period after integrated regulation and before 1999 (including 1999) is the period before integrated regulation. The natural Yellow River basin runoff is represented by natural runoff in Huayuankou station which is a control station for important water area. Due to the no – flow situation in 1990s is the most serious and the damage to estuary environment is the most severe, the data analyzed in this paper is mainly after 1991.

According to the statistics from 1991 to 1999, the average annual runoff of the Yellow River basin is 44.2 billion m^3, 21% less than the years average. The average annual runoff at Lijin is 12.8 billion m^3, in which the runoff from March to June is 1.6 billion m^3. After integrated water regulation, the average annual runoff of the Yellow River basin is 41.5 billion m^3 from 2000 to 2006, 26% less than the years average; the average annual runoff at Lijin is 13.2 billion m^3, in which the runoff from March to June is 3.21 billion m^3 (see Table 2). Since 1991, although the natural average runoff after the regulation is 2,700 million m^3 less than that before the regulation in the whole basin, the average runoff entering the sea is 400 million m^3 more than that before the regulation. The ratio between the runoff flowing into the sea and the total runoff of the basin increased 2.0%. The most obvious difference is the runoff entering the sea from March to June, the average volume of which is 3.21 billion m^3 after regulation, doubling than before the regulation.

Table 2 Statistic of the Yellow River runoff in Lijin Unit: 10^8 m^3

Year	Runoff in Huayuankou	Runoff in Lijin		Proportion on the basin(%)	
		Whole year	March ~ June	Whole year	March ~ June
1991 ~ 1999	442	128	16.0	28.4	4
2000 ~ 2006	415	132	32.1	30.1	8
1991 ~ 2006	430	130	23.1	29.2	6
1997	332	18.7	10.9	5.6	
2001	323	46.35	12.59	14	
2002	300	41.6	6.3	14	

Since the regulation of the Yellow River water resources, the water quantity flowing to the lower reach keep in a low level. Especially from 2000 to the first half of 2003, the runoff is 40% less than that in ordinary years. The runoff in the basin in 2001 is 32.3 billion m^3, and in 2002 is 30 billion m^3, both of which are less than that (33.2 billion m^3) in 1997. But due to the integrated regulation of water resources, no – flow didn't occur and the runoff entering the sea was twice of that in 1997.

4 The influence of water resources regulation on estuary environment

4.1 Continuous freshwater recharge and restoration of wetland

Since 2000, no – flow has never occurred in the lower Yellow River, and freshwater was recharged continuously to the estuary region, thus the freshwater level rose 0.4 m averagely annually. Furthermore, due to scientific allocation of water resources, storage of water in Xiaolangdi reservoir before flood season and continuous water and silt regulation after 2002 big water flow entrained high sediment was released to the lower reach. As a result, large amount of water and silt entered the wetland and sea respectively, and thus sea water intrusion was contained and the wetland restored gradually. According to statistics, from 2000 to 2006, more than 40,000 ha of saline land was restored to wetland and the Yellow River Delta environment was obviously improved.

4.2 Obvious increase of water quantity flowing into the sea from March to June and enhancement of water assurance rate for biology in critical growing period

From March to June is the springtime in estuary region and all living things are resuscitating at this time, plant sprouting and animal reviving from hibernation, so the water demand of which is very huge in this period, and it is also the peak period for irrigation. At present there are lots of methods to calculate environmental flow. The result of monthly environmental flow in estuary region researched by Liu Xiaoyan, the deputy chief engineer, is shown in Table 3. The insurance flow is the flow which can balance social and naturally ecological functions of the river in certain period, the lower – limit flow is "acceptable instantaneous minimal flow". Comparing the monthly flow in Lijin showed in the table below, we can discover that the period in which the environmental flow is difficult to be fulfilled is from March to June. Especially before the water regulation, no – flow occurred every year, so even the lower – limit flow was difficult to fulfil. As shown in Table 2, the runoff entering the sea from March to June after regulation is twice than that before the regulation;

the assurance rate of water supply for biology in critical growth period and the wetland area both increased; thus it promoted the growth and propagation of plants and animals, and the restoration of ecosystem as well.

Table 3 Monthly environmental flows in estuary region Unit: m^3/s

Index	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Assurance index	90	110	140	310	310	200	430	560	500	400	240	110
Floor index	55	65	90	95	95	120	265	340	300	250	150	65

4.3 Inshore water quality improved continuously, species and amount of fish increased

Because no – flow has never occurred in the past 7 years, the water quality and the environment of the Yellow River estuary got obvious improvement. The increase of wetland area and rising of fresh water level created a good environment for fish living and breeding. The amount of inshore economic fishes increased year by year and fishing season of rare species began to appear.

In summary, after the integrated water regulation, no – flow has never occurred, and continuous freshwater was delivered to estuary region. At the same time the water volume in estuary for biological use in critical growth period was increased. The water source of wetland ecosystem, of which the main water sources is from the Yellow River was replenished, and then result in restoration of wetland, improvement of water quality and local ecology, and the harmonious relationship between human and nature. According to spot investigation, 4,238 ha of wetlands in the Yellow River Delta were restored to used to be at present; the vegetation area increase year by year and the reed area has increased to 52,000 ha; the wild plants species has been up to 407, and 14 national rare plant species are also settle down. Copper fish which disappeared in 1880s began to appear massively, and Yellow Rive saury which disappeared years ago also recovers in the estuary. The bird species in the nature reserve increased from 187 in the beginning of 1990s to present 283; 459 species of rare biology has been discovered, which nearly is double with that before the regulation. Besides, nutrient salt entering the sea in non – flood season is increased, which has created positive influence on inshore hydrophytes, fish diversity and fishery.

5 Recommendations for the regulation of environmental flow in the Yellow River estuary

The Yellow River belongs to water scarcity river basin, and the contradiction between supply and demand of the water resources is very outstanding. After the integrated water regulation, though no no – flow was realized in past 7 years, the water situation of productive use occupying environmental use still exists. In certain periods, the runoff in Lijin still cannot meet the quantity index, especially in dry years of the Yellow River, which influence the healthy development of estuary ecosystem in some extent.

In recent years, Yellow RiverCC put forward the new concept of maintaining the healthy life of the Yellow River, which is regarded as the ultimate goal of the Yellow River harnessing, and how to deal with the problem of estuary environmental flow is one of the main parts. And "the Byelaw of Yellow River Water Regulation" issued on August 1st, 2006 expresses explicit request for water regulation that all of the domestic, productive and ecological water use should be taken consideration and an overall plan should be made also. Therefore, in future regulation of the water resources, the regulation of environmental flow should be paid more attention; the environmental flow required in different periods in estuary region should be taken deep research; crop planting principle of "determining production according to water supply" should be advocated, and the water situation of productive use occupying environmental use should try to be avoided.

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The Function of Water Resources Optimal Disposition of the Key Regulation Projects on Heihe Trunk

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Abstract: Water resources are scarce in Heihe basin and the contradictory if water consumption is prominent. The inter – province water transferring is carried out on the Heihe basin in order to alleviate the situation that the ecological environment worsens day by day in downriver of Heihe. Because there is no water volume adjustment project in Heihe trunk. The span of the water adjusting is wide and the loss of the water distribution along the river course is very big, so it couldn't provide essential water volume during the time of adjusting water to the downriver, and the efficiency and benefit of water resources using is very low. In the season of summer irrigation, because of the specific way of irrigation and pilots in middle reaches, the situation that "comes more then uses more" is difficult to change. The water resources waste still exists. While the water is less in spring, it is always dry during the critical moment. In order to enable the limited water resources of Heihe to be under the scientific management, the reasonable disposition, the highly effective use, and to realize the sustainable development of the economic society in Heihe basin and to improve the ecological environment effectively, it is urgent to construct key projects to store and regulate in Heihe trunk.
Key words: project to store and regulate, optimization disposition of water resources, Heihe

1 Overview of Heihe basin

Heihe is the second longest inland river in China. It passes through QingHai Province, GanSu Province and Inner Mongolia Autonomous Region. The south of the basin extends to Qilian Mountain, the east neighboring with Shiyang River and the west with ShuLe basin. Its area is 142,900km^2, including some of areas in Gansu Province being 61,800 km^2, in Qinghai Province being 10,400 km^2, and in Inner Mongolian approximating 70,700 km^2. Heihe basin has 35 small branches, along with the increasing of water consuming, gradually, part of branches loses the surface water relation with the trunk, forms east, center, and west three independent sub – river systems. The sub – river system of Eastern part is Heihe trunk, including Heihe trunk, Liyuan River and more than 20 small branches along the mountain, its area is 116,000 km^2. The trunk of Heihe is 821 km long, above Yingluoxia is the upstream. The river course is 303 km long and its area is 25,600 km^2. The annual precipitation is only 140 mm. Below the Zhengyixia canyon is the downriver. The river course is 333 km long and its area is 80,400 km^2. The annual evaporative reaches as high as 2,250 mm, so the climate is extremely dry, the arid index reaches 47. 5. It belongs to the extreme arid area. The sandstorm is extremely serious, and it is the one of source areas that mainly comes from for north in our country.

2 Rule of runoff

2.1 Regional distribution of runoff

The precipitation is the main source of supply in Heihe area, and the water volume of the river changes along with the rainfall. The discharge process is corresponding to the rainfall process. The main water volume of the river is centralized in the flood season. But in the mountain region is the solid precipitation, part of which transforms into the form of glacier which melts to supply the river again. In non – flood seasons the runoff of the river is supplied mainly by the ground water of mountainous area.

The runoff of Heihe basin form the completely different runoff areas about nature from the source to the offal, named the forming, the utilization and the disappearing area of the runoff. The south of the Qilian Mountainous area is the forming area of the runoff, where the topography is high and cold, the precipitation is more, the temperature low, the evaporation weakly. And the glacier snow can grow. So it is good to the formation of the runoff. Along with the increasing catchment area the annual rate of flow increases also and achieve the maximum when leaves the mountain. In front of QiLian Mountain there is plain formed by the flood. Oasis agriculture development zone of Zhangye, Linze and Gaotai and Dingxin irrigation area in the downriver are the runoff use area. It finally vanishes along with the quote, the evaporation and the infiltration along the runway such as the oasis of Ejina, so it is the separate area of the runoff.

The annual mean discharge of Hydrologic station of Yingluoxia, which is the control station when the trunk of Heihe river flows out of the mountain, is 49.3 $m^3 \cdot s$. The total rate of flow is 15.8 billion m^3, and the modulus of runoff is 4.900 $L/(s \cdot km^2)$. The annual mean current in the upstream of west Zhamashenke station is 22.7 m^3/s, and the rate of flow is 0.715,9 billion m^3, accounts for 46.0% of the total rate of flow coming out of the mountain. The modulus of runoff is 4.947 $L \cdot (s \cdot km^2)$. The annual mean discharge in east QiLian station is 14.0 m^3/s, the rate of flow is 0.441,5 billion m^3, accounts for 46.0% of the total rate of flow. And the modulus of runoff is 5.710 $L/(s \cdot km^2)$. The rate of flow between the above two station and Yingluoxia is 0.397,3 billion m^3, accounts for 25.6% of the total rate of flow come out of the mountain, and The modulus of runoff is 4.245 $L/(s \cdot km^2)$. The respective characteristic value of the runoff of the area that produces flows is shown in Table 1.

Table 1 The characteristic values of the runoff of Heihe area that produce flows *

Station	Area (km^2)	Percentage of the area (%)	Mean discharge (m^3/s)	Natural water coming ($10^8 m^3$)	Modulus of the runoff ($L/(s \cdot km^2)$)	Sector area (km^2)	Coming water of the sector ($10^8 m^3$)	Modulus of the sector ($L/(s \cdot km^2)$)
Zhamashenke	4,589	45.9	22.7	7.159	4.947			
Qilian	2,452	24.5	14.0	4.415	5.710			
Yingluoxia	10,009	100	49.3	15.547	4.900	2,968	3.973	4.245

2.2 Annual assignment of runoff

The annual assignment of the runoff is distinct because of the different supplied condition. The general rule is: in the winter, as a result of the freezing, the supply of the runoff depends on the ground water, and the minimum discharge appears in January or February, which is the dry season. From January to March, the quantity of coming water accounts for 7.1% of the year. The temperature obviously elevates after April, and the stored snow melting and the ice on the network of waterways defrosting form the spring flood. The discharge has a remarkably increasing. The coming water between April and May accounts for 11.8% of the year, which is the spring irrigation time for the farmland. There is more precipitation during the summer and the autumn. And it is the time that the river has the flood. From June to October, the quantity of coming water accounts for 74.7% of the year. The quantity of the discharge each month account for total quantity of the year is shown in Table 2.

Table 2 Quantity of the discharge each month in Yingluoxia account for that of the year

Month	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Des	Flood time	Year
Percentage (%)	2.1	2.3	2.7	4.4	7.4	13.0	21.8	19.7	13.8	6.4	3.8	2.6	74.7	100

2.3 Annual changes of runoff

The annual changes of runoff are usually expressed by the change modulus or annual extreme ration (maximal, minimal annual rate of flow ratio). *cv* reflects runoff process changes degree of area relativity. If the number of the value is big, it means the runoff changes greatly acutely, and it is disadvantageous for water resources use. Value for the Yingluoxia station is 0.16, and the annual extreme ration is 2.09, which is our country low value area that annual changes of runoff in Northwest. The variation explaining runoff of Heihe River is relatively stable.

The change of runoff process generally looks like serration with high - frequency oscillation, and the trend is difficult to find. The annual average rate of flow process line of Yingluoxia station is drawn in Fig. 1. Annual rate of flow and the time trend relation are expressed by linear equation:

$$Q_{y,t} = 45.726 + 0.126,6t \quad (1)$$

where, $Q_{y,t}$ is average discharge of Yingluoxia Station; t is the time {year of 1944, $t = 0$}.

Known from equation (1), the slope of the linear equation $k = 0.126,6 > 0$, shows that as a whole, the trend of the change in long range of the runoff is ascending slowly.

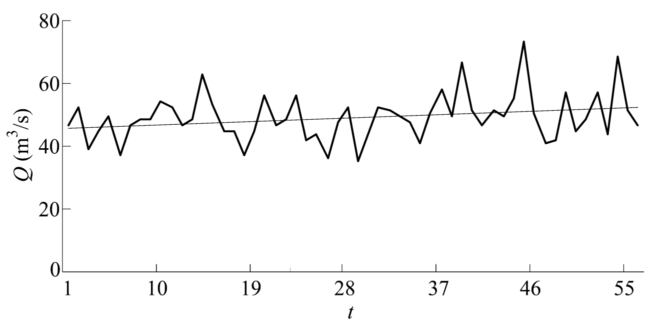

Fig. 1 The annual average hydrograph of Yingluoxia Station

The residual mass diagram of frequency factor of the annual runoff in Yingluoxia Station is shown in Fig. 2 ($\sum (k_i - 1) - t$), with comparative analysis in it. It can perceive change of abundant dried up annual group law obviously right away. Runoff change process has water abundantly, but the general trend abundant in coming down before 1979. After 1980, individual year of runoff is partial to dried up, but total trend in change process in rising slowly. This long irregular persistence changing of runoff is big dimension atmosphere circumfluence characteristic effect in one hand, in the other hand, the changes of the regional runoff is long, middle and the short cycle play an important part in it.

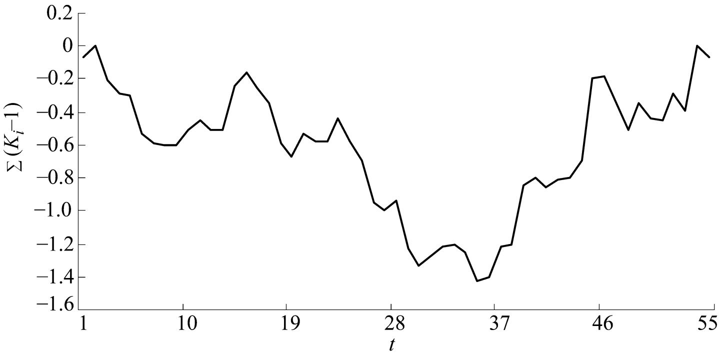

Fig. 2 Residual mass diagram of frequency factor of the annual runoff in Yingluoxia Station

3 Spreading rule of the river channel

3.1 Spreading time of the stream

According to the statistic analysis of the gorge spreading process over the years from the Yingluoxia station to Zhengyixia Station, when the discharge in Yingluoxia Station is 300 ~ 350 m^3/s, the spreading time is about 33 h and when it's 400 ~ 500 m^3/s, the spreading time is about 25 h. When the discharge is 600 m^3/s in Yingluoxia Station which is the critical discharge of the trunk tidal flat of Heihe River and the flood spreads most quickly under that flowing level, which needs approximately 20 ~ 25 h from the Yingluoxia Station to Zhengyixia Station. If it exceeds that rate of flow level, the spreading time will increase oppositely.

According to the statistic analysis about the propagation time of every channel segment streams from 2004 to 2006, the propagation time from Yingluoxia to Shaomaying is stabilizes relatively, and that of the following channel segment past Shaomaying stream is bigger. Every channel segment streams spreading speed and lasting time can be seen from the Table 3.

Table 3 Every channel segment streams spreading speed and lasting time segment

Series	Discharge of YingLuo xia (m^3/s)	Yingluoxia – Zhengyixia (185 km)		Zhengyixia – Shaomaying (98 km)		Shaomaying – Langxin mountain (66 km)		LangXin Mountain – East Seaside (189 km) Time	
		Time (h)	Veloeity (m/s)	Time (h)	Veloeity (m/s)	Time (h)	Veloeity (m/s)	Time (h)	Veloeity (m/s)
1	100	60	3.09	130	0.75				
2	100 ~ 150	46	4.02	74.3	1.32	19.2	3.44	132.8	1.42
3	100	51	3.61	80.5	1.22	32.0	2.06	149.5	1.26
4	100 ~ 150	38	4.87	60.5	1.62	36.5	1.81	120.2	1.57
5	100	61	3.02	94.4	1.04	23.0	2.87	77.1	2.45
6	100	56	3.32	80.2	1.22	30.5	2.16	208.8	0.91
7	100 ~ 150	44	4.25	62.5	1.57	41.3	1.60	73.6	2.57
Average		51	3.72	83	1.25	30.4	2.32	127	1.70

Seeing from the table, when the discharge of the Yingluoxia is about 100 m^3/s, the spreading time is about 50 h, and the time from Yingluoxia to Shaomaying Channel is about 80 h, and from Shaomaying to Langxin Mountain is about 30 h, Langxin Mountain to the seaside is about 120 h. Because the channel from Zhengyixia downwards is so wide, shallow, scattered and disordered that the loss of leakage is big, the factor to the speed of water head in the runway is comparatively complicated, such as the quantity of the water coming from upstream, the situation of water crossing preliminary etc. which make the spreading speed have very big difference. Since the quantity of the water arid the degree of dries about the channel in the earlier stage are different, the spreading time difference is about 2 times.

3.2 Analysis of water lost in transfer

Because the trunk of Heihe River is wide, wide, shallow, scattered and disordered, the loss of water is serious, especially in the downriver, the loss of evaporation and leakage is especially extremely grave. The loss rate is about 25 % from Yingluoxia to Zhengyixia. The rate of flow is small in central dispatch time, and the rate of water loss is amount to 35 %, the changing of loss from Zhengyixia to LangXin Mountain is bigger. With the bigger sluice water during central dispatch scheduled time, the lost water of runway conveying obviously decreases, and the rate of conveying water loss changes from 20 % to 70 %. Each channel segment conveying water loss and the rate of which when the coming water is different is given in Table 4.

Table 4 Channel segment conveying water loss and the rate of it as different coming water

Project series	Discharge of Yingluoxia (million m^3)	The lose of the sector in Million m^3		The rate of lose of the sector (%)	
		Yingluoxia – Zhengyixia	Zhengyixia – Shaomaying	Yingluoxia – Zhengyixia	Zhengyixia – Shaomaying
1	181	41	69	23	49
2	265	61	51	23	21
3	69	21	32	30	67

4 The founction of storing and regulating project in allocation of water resources

4.1 Enhancing the safeguard level on the fulfilling of water diversion target effectively

Because of the special way of irrigation and pilot in middle reaches, the more water flow in, the more will be discharged and the situation can not be thoroughly changed. water wasting will still occur. It is difficult to accomplish the target in Zhengyixia in wet year. After analyzing the annual runoff changing trend of Yingluoxia, we can see that the general trend is ascending. The odds of more flow are more probably. In recent years, the measurement of water dispatch in crucial water transfer period and irrigation interval from July to October is that shut up all line, centralize to sluice. The locked period has lasted about 70 days long. Even so, the discharges of Zhengyixia are 0.363 million m^3, 0.441 million m^3 and 0.509 million m^3 in three periods of different guarantee rate years. When the coming water is mean annual or has 25 % guarantee rate, the annual sectional diversion target of Zhengyixia will respectively lack 0.079 million m^3 and 0.151 million m^3. So we can not assure the discharge target of Zhengyixia only by concentrating the water in dispatching period. We have to store the superfluous water of irrigation period by storing project, and then centralize to sluice in water transfer period. Therefore, we can not only lessen the waste of water, but also can raise the level of safeguard about the target of Zhengyixia that to be accomplished efficiently.

4.2 Improving the efficiency and benefits of water transfer effectuvely

Channel of Heihe downriver is wide, shallow, scattered and disordered, so the quantity of water is lost seriously. According to the present runway streams' speed and the lost water condition, it needs 10 to 15 days to centralize. When the accumulated quantity of water is reached 120 ~ 150 million m^3, it can ensure that entire main channel has flow and convey water to the east seaside. But we need to consider guaranteeing reaching every using water family fundamental, irrigation and east residence need to maintain, certain water surface to maintain village use, all together once centralized conveying water reaches to 350 million m^3. Because of annual Heihe trunk water distribution, conveying water expects grave deficiency of quantity of water all together and time is limited (about 10 days), in addition small rate of flow conveying water loss is graver and having no way to deliver to east residence, concentrating translating water is often died on the vine. Therefore, only by project of tune harbors conveying water to downriver concentrate, which is improved translating water efficiency, providing the quantity of water between concentrating conveying water time.

4.3 Improving the safeguard degree of irrigation in midstream effectually and reduce the waste of water resources

Because the trunk is short of project of storing and regulating, water deficient is serious in June and July which is the essential time for irrigating. It often brings drought of 'cutthroat'. In order to relieve the problem of the water deficient in irrigation, midstream irrigation area has built 27 plain reservoirs. The effective storage is 48.69 million m^3, which increased evaporation and the amounts of leakage. The irrigating gates of the irrigation area are so many, the canal is so long and disordered, that the waste of water resources is serious. Because discharge is small in concentrated water transfer period, and the time is long, between which and irrigation the contradiction is gradually seriously. After Huangzang Temple Reservoir is built, we can short the shutting time, slow down the contradiction between water used in midstream irrigation and water used to be regulated, supply water to midstream at the right moment, replace the plain reservoir, improve the condition of pilot in midstream irrigation area, promote the function of the saving water and reforms in the irrigation area, and elevate the utilization ratio of the water resources.

4.4 Supplying water to downriver properly and realizing the rational allocation of water resources and use effectively

The lower reach of the Heihe River is mainly natural vegetation, relatively not very strict to the request of water using process, but also has the time of crucial water using. Natural vegetation irrigation scheduled can also be divided to spring irrigation (March to April), summer irrigation (July to August) and autumn irrigation (September to October). Irrigation in spring among them is the most important time to natural vegetation of downriver, when we should carry out sufficient water to irrigate properly, which play a very important part in the growing of natural vegetation. Because the quantity of water is limited in spring and it's the time of using water peak – hour in midstream, there is no way to transport the necessary water for ecology to downriver. After mainly regulation project is built, it is able to control the superior of source of the trunk runoff of Heihe. By adjusting nature coming water process, increasing water entering effective to downriver area in spring irrigation, satisfy the necessaries water request that natural vegetation growth in downriver mostly.

5 Conclusions

The middle and lower reach and of Heihe basin is extremely arid and the ecological environment is frail. It is difficult for the region water resources to satisfy the development of local social economy. The contradictory about water is prominent in the history. Because the water used in agriculture irrigation in upstream is massively, which occupies the water used in ecology, the worsening ecological environment downriver is intensified and the contradictory about water is extremely prominent. Considering to realize the goal of the construction and the protection about the ecology, to coordinate the relations about the water used in product, life and ecology and to solve the problem that exist in the unified management dispatch of water resources and so on, it is urgent to construct the backbone project in trunk of Heihe, to consummate the method of water regulation and to establish and consummate the project system of Heihe water regulation management. Huangzang Temple Reservoir to be constructed will be able effectively to adjust the water resources later and supply water to the midstream and downriver at the right moment. It can substitute the reservoir in the plain of midstream, reduce the loss of the evaporation and the leakage, improves the condition of water conducting in the area of midstream and promote the function of the saving water and transformation in irrigation area and so on. By the implement of the reservoir dispatch, we can dispose the assignment of water for various users reasonably and guarantee water supplied to ecology in the oasis of Ejina.

Analysis of Trans – basin Diversion Project Impact on the Yellow River Water Resource Distribution Pattern

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Abstract: The Yellow River water distribution plan, which was approved by the State Council in 1987 has established the basis for the river water resource distribution before operation of the South – to – North Water Diversion Scheme (the Scheme), which consists of the east, middle and west line projects, together with the Yangtze, Huai, Yellow and Hai Rivers, forming "four transversal and three longitudinal" water routes for "South – North regulation and East – West coordination". The paper analyses the water resource situation of the Yellow River, scope of water supply by all diversion schemes and water supply targets, evaluates the position and role of the Scheme in water resource distribution of the river basin, and concludes that with the east and middle line projects under construction, the unified planning for resolving water shortage of the river basin still requires urgent implementation of the west line project.

Key words: distribution of water resources, Yellow River, trans – basin water diversion, west line South – to – North water diversion project

1 Status and characteristics of the Yellow River water resources

The Yellow River runs through nine provinces (autonomous regions) of Qinghai, Sichuan, Gansu, Ningxia, Inner Mongolia, Shaanxi, Shanxi, Henan and Shandong with catchment area of 795,000 km^2 (including inland area of 42,000 km^2). As indicated by the 1919 to 1975 flow series, mean annual natural runoff is 58 billion m^3, and the reaches upstream of Lanzhou mainly receives clear flow, being 55.6% of the total, the middle reaches of Hekouzhen to Sanmenxia are the main sediment – yielding area, being above 90% of the total, and runoff only of 32.0%. The lower reaches have contribution of fewer tributaries such as the Jindi and Dawen rivers, with only 3.6% of the total runoff, and most of the portions has become "suspended river" due to sedimentation.

Water resources of the Yellow River are characteristic of deficient volume, uneven areal distribution, large annual runoff variation, uneven distribution in the year and long continuous low – flow portions. More sediment and less water, uneven temporal and areal distribution and unharmonious water – sediment relationship are the bottleneck in the difficulty of the river management. The sediment – water characteristics, and resources, economy and population distribution in the basin have determined that in utilization and distribution of the river water resources, it is a must to concurrently consider water demand of the upper and lower reaches, the left and right banks as well as different sectors, and to coordinate water utilization by both economy and society as well as by sediment transport and eco – environment in different river reaches and time durations.

The Yellow River Basin is short of water resources with water of 488 m^3 per capita, being 22% of the national average; and water of 220 m^3 per mu of cultivated land, being 12% of the national average. With economic and social development of the river basin, the conflict of water demand and supply has become severely acute. In accordance with the preliminary comprehensive planning of the river water resources, by considering of surface supply works, proper exploitation of groundwater and sufficient water saving, by the level years of 2000, 2020 and 2030, water shortage of the river basin is respectively about 6.68 billion m^3, 11.45 billion m^3 and 14.95 billion m^3. Water shortage out of channel is respectively about 4.92 billion m^3, 8 billion m^3 and 10.93 billion m^3. That is to say without trans – basin water diversion the situations of water demand and supply will be very stringent in the future.

2 Existing water resource distribution pattern of the Yellow River Basin

The Yellow River is the important water source in northwest and north China, and economic and social development depends on the river water very much. Meanwhile, the river is highly laden with sediment, and for the river management and flood control, in the river development and utilization planning, a certain volume of water for transporting sediment into the sea and eco – environment shall also be reserved. For coordinating between regions and sectors, strengthening of overall regulation, and water utilization in a planned manner, and with the principle of unified consideration and overall arrangement, the State Council approved in 1987 the Yellow River available water distribution plan (called "87 water – distribution plan") before operation of the Scheme, by which the river volume available for distribution is 37 billion m^3 (Table 1) with a reserve of 21 billion m^3 for sediment – transport and eco – environment in channel on the basis of mean annual natural runoff of 58 billion m^3. Because of large yearly inflow variation, and for guaranteeing eco – environmental water use in channel for the low – flow year, the principle of "increase in high – flow year and decrease in low – flow year" is carried out in implementation.

Table 1 The Yellow River available water distribution plan

Province (autonomous region)	Qinghai	Sichuan	Gansu	Ningxia	Inner Mongolia	Shaanxi	Shanxi	Henan	Shandong	Hebei, Tianjin	Total
Annual water consumption ($10^8 m^3$)	14.1	0.4	30.4	40.0	58.6	38.0	43.1	55.4	70.0	20.0	370.0

The "87 water – distribution plan" is the first of this kind for large rivers in China, being the outcome of the river water shortage and the supply and demand conflicts. The execution of the plan has achieved good effect in coordinating water resource development and utilization between the river reaches and promoting planned and economic water utilization, being a great contribution to economic and social development along the river and a safeguard for the river development and utilization. Before operating of the Scheme, without inflow from other basins, the "87 water – distribution plan" will still be the basis for the normal – flow year, and continue to guide for the river management and dispatching.

With economic and social development and intensification of human activities, in recent years, the total water volume of the river tends to decrease. In accordance with the preliminary comprehensive planning of the river water resources and the 45 – year water series of 1956 to 2000, mean annual runoff above Lijin is 53.48 billion m^3, being a decrease of 4.5 billion m^3 compared to the 56 – year water series of 1919 to 1975 adopted by the "87 water – distribution plan". Water shortage becomes more stringent.

3 General arrangement and water supply target of the scheme

In accordance with the General Planning of South – to – North Water Diversion Scheme approved by the State Council in December of 2002, the Scheme consists of the east, middle and west diversion routes.

The east line project has a planned total water diversion of 14.8 billion m^3, including the first phase of 8.84 billion m^3. It pumps water at Jiangdu, Yangzhou on the lower reach of the Yangtze River and supplies water through Jing – Hang Canal and the parallel river channel to the east Huang – Huai – Hai Plain and Jiaodong area. The purpose is to supply water to the route and Jiaodong area for municipal life, and environmental and industrial use, and improving agricultural water use in the north Huai River area, and when necessary, for agricultural and environmental use in north China.

The middle line project has a planned total water diversion of 13 billion m^3, including the first phase of 9.5 billion m^3. It diverts water from Danjiangkou Reservoir on the Hanjiang, supplies water through excavated canals, by way of the west boundary of Huang – Huai – Hai Plain, passes the Yellow River at Gubaizui, west of Zhengzhou, and runs along west of the Jing – Guang railway by gravity all the way. The purpose is to supply water for municipal life and industrial use in Beijing, Tianjin, and Hebei, Henan and Hubei Provinces, as well as agricultural and other use in some areas.

The west line project has a planned total water diversion of 17 billion m^3, including the first and second phases of 9 billion m^3. Water is diverted from the dams to be built on the Tongtian River, Yalongjiang, a tributary of the Yangtze River and the upper reaches of the Dadu River by way of the 304 km – long tunnels through the ridge of the Yangtze and Yellow Rivers, and runs into the Yellow River by gravity. The scope of water supply covers the whole Yellow River Basin and adjacent west inland river area. The purpose is to supply water for national economy in the upper and middle reaches, keep within limits the degrading of eco – environment, supplement ecological water use in the channel and improve the basic functions.

The Scheme consists of three diversion routes of the east, middle and west works with the specific scope of service, targets and foci, together with the Yangtze, Yellow, Huai and Hai Rivers forming an interconnected and reasonable water network to facilitate regulation between South and North, and East and West and effectively alleviate water shortage in the river basins, Jiaodong area and part of the Northwest inland area.

4 Analysis of the scheme affecting the Yellow River Basin water resource distribution pattern

As planned, the east and west line projects will not supplement water to the Yellow River channel, but after operating of the projects, water supply to the two bank areas will reduce the dependence of water use for economic and social development on the Yellow River, objectively improving the Yellow River water distribution pattern. The west line project will divert water to the upper reaches of the Yellow River, covering a large service area and with good regulating conditions, which will increase water for sustainable economic and social development and sound maintaining of eco – environment in the upper and middle reaches, as well as improve basic function of the channel and the guarantee of water supply in the lower reaches.

4.1 Implementation of east and middle projects actively improving the present Yellow River water resource distribution pattern

4.1.1 Importance of east and middle projects to maintaining the water distribution pattern of the Yellow River upper and middle reaches

Water supply from the Lower Yellow River serves Henan, Shandong, Hebei and Tianjin Provinces (City), which are mainly located in the Hai and Huai River Basins. The three basins are all short of water, but national economy has been developing rapidly depending on excessive utilization of water resources. By risking of flow break – off in the Lower Yellow River, water of around 9 billion m^3 is supplied to the adjacent basins, which is from one to another poor water basin, being the last solution for all the three basins short of water. After the east and middle projects begin operation, additional water is supplied to the Huai and Hai river basins and guarantee of water supply is increased, reducing the risk of excessive water diversion from the Yellow River, and correspondingly improving the water distribution pattern in the middle and Lower Yellow River. Water supply to Hebei and Tianjin will then be reduced, and actively alleviating the water demand and supply conflicts in the Yellow River Basin.

4.1.2 Analysis of trans – basin water supply in the lower Yellow River replaced with east and middle projects

Being highly deposited in the lower Yellow River, the suspended riverbed is convenient to supply water to other basins. As recorded in 1980 to 2000, annual water supply was 9.763 billion m^3, including 0.867 billion m^3 to Henan, 8.82 billion m^3 to Shandong and 0.397 billion m^3 to Hebei and Tianjin.

Water supply out of the basin is for agricultural irrigation in Henan and Shandong provinces, and mainly for domestic, industrial and living use in Hebei and Tianjin. In determining water diversion by the east and middle line projects to target areas, the same amount supplied by the Yellow River remains effective to Henan and Shandong Provinces, but the volume available from the river to Hebei and Tianjin is reduced from 2 billion m^3 to 0.5 billion m^3 in Hengshui and Cangzhou of Hebei, and the remaining to other provinces (autonomous regions).

4.1.3 Supplementation of east and middle line projects to the Yellow River channel when necessary

The east and middle line projects cross the Yellow River respectively near Dongpinghu and Gubaizui through inverted – siphon tunnels, not directly supplying water to the Yellow River, and when necessary, it is possible by the existing recession gate of Dongping Lake for the east line project and the gate on the south bank for the middle line project.

YREC, related colleges and institutes carried out researches of supplementing water to the Yellow River from the east and middle line projects in 2004 and 2005. The analysis shows the three – phase works of the east line project diverts total amount of 14.8 billion m^3, and if supplementation is in July to September, mean annual amount could be 0.55 billion m^3 to 1.24 billion m^3; for the whole year, the amount could be 0.93 billion m^3 to 2.46 billion m^3. The middle line project of the current scale could supplement water of 0.213 billion m^3 on annual average to the river in 2010, and 0.279 billion m^3 in 2030.

Supplementing water by the east line project will have good effect on sediment reduction in the channel of Shandong Province, as well as maintaining basic flows in the channel and eco – environment in estuary. Being limited by the water source, and concurrent occurrence of either high or low flows both of the Hanjiang and the Yellow River, supplementation is less, and the effect on sediment reduction is limited.

4.2 The scheme basically improving water resource distribution pattern in upper and middle Yellow River reaches as well as water resource development and utilization in the lower reaches

In view of areal distribution of the river runoff, the main source area is above Lanzhou, which seems to be able to satisfy the water demand in the upper and middle areas, but the overall analysis for the river management, and economic and social development in the river basin and adjacent areas, for maintaining sediment – transport and ecological flows in the portions of Ningxia – Inner Mongolia, Hekouzhen to Tongguan and lower reaches, and for economic and social development in the lower areas, water use in the upper and middle areas will be largely limited, which has been fully reflected in the "87 water – distribution plan".

4.2.1 Water shortage restricting social and economic development in upper and middle areas

The upper and middle areas including Gansu, Ningxia, Inner Mongolia, Shaanxi and Shanxi Provinces (autonomous regions) have very rich land and mineral resources, are the most important coal base in China with coal in all varieties and in concentrated locations. It has advantages for developing in large scale of coal and power joint operation, coal liquefaction and coal chemical industry to establish the energy base of coal – power – liquefied coal and coal chemical industry with the premise of sufficient water supply. Water consumption in provinces (autonomous regions) of the upper and middle areas has reached or even exceeded the quota, and many new energy projects planned have been put aside because of water shortage, and with the water – right transfer carried out, part of the quota can be transferred for industrial use, but the volume is limited and not a long – term measure.

The areas of the upper and middle reaches have scarce precipitation and arid climate, being ecologically vulnerable and sensitive to changing of climate. For a long – term period, with growth of population, a large area of land cultivation without irrigation available and overgrazing on grassland led to desertification, vegetation degradation and outstanding eco – environmental problems. The Daliushu Ecological Zone planned at the boundaries of Jingxia, Inner Mongolia and Shaanxi has a total planned area of around 5 million mu for ecological resettlement, forest and grass irrigation and improving of eco – environment. The implementation requires water taking of around 1.5 billion m^3 from the Yellow River. And also being limited by water shortage and quota, the ecologic zone can not be built on a large scale.

4.2.2 The Scheme basically improving situation of water shortage as well as development and utilization of water resources in the lower reaches

The preliminary study for water diversion by the Scheme shows the first phase project diverts water of 8 billion m^3, including 3.5 billion m^3 into the river channel for sediment transport and ecological use, and 4.5 billion m^3 for municipal life, industry and Daliushu Ecological Zone. After the project begins operation, water supply for municipal life of major cities in the upper and middle areas will be guaranteed, basically improving the water situation for industry and the energy base as well as local eco – environment, and fundamentally resolving break – off of flows in the middle and lower stem channels.

Water use for all river reaches is interconnected, and the quota exceeding upstream will unfavorably affect the downstream use, particularly in low – flow years, the conflicts among the upper, middle and lower reaches are very acute, and the quota exceeding upstream usually results in difficulty in water use downstream, flow break – off and degradation of eco – environment in estuary. Since implementation of unified water dispatch, monitoring is strengthened for all the provinces (autonomous regions), and although administrative mandatory approaches ensure no break – off of flows, in unusually dry years, water crisis still exists in the lower reaches.

Water diversion by the Scheme on the one hand supplements water to the Yellow River, largely improving the conditions of water supply in the upper and middle areas and increasing the guarantee; on the other hand, reservoirs on the stem Yellow River regulate high flows and supplement for low flows, providing more chance to unified dispatch and management of the river water resources and having active effect on development and utilization.

4.3 The scheme supplementing water for sediment transport and ecological use, having favorable effect on maintaining the basic pattern of the channel and healthy ecology of the river

4.3.1 Maintaining basic pattern of the river channel and healthy ecology being premium of the Yellow River water resource development and utilization

At present, the level of the river development and utilization is relatively high, already being higher than its bearing capacity, and bringing about a series of serious problems. With the conditions of limited water resources and economic and social development highly depending on the river water, the river development and management, on the one hand, shall be carried out in any way for supporting economic and social development of the basin and relevant areas, and on the other hand, for maintaining basic pattern of the river channel and healthy ecology, which is the premium of the river development and utilization. Maintaining healthy life of the river is the basis for safeguarding of sustainable economic and social development.

4.3.2 Riverbed sedimentation and rising, flow break – off and serious water pollution are prominent phenomena of the river "illness"

Since mid of 1980s, as inflow of the Yellow River has become increasingly less, and with increase of water use for economic and social development in the basin, water volume entering into the lower river is rapidly decreasing, and water and sediment are more unharmonious, leading to serious sedimentation in the lower river, narrowing of the main channel, overflowing with even small discharge, badly affecting the people's life and production in floodplains. Meanwhile, the "secondary suspended river" has been upgrading, threatening flood control in the lower reaches. In the upper Ningxia – Inner Mongolia section, as a great amount of sediment has been depositing, part of the riverbed portions has risen by over 2 m, tending to become suspended; since 1980s the Hekouzhen – Tongguan section has been rising by 1 m to 2 m, the elevation difference at two sides of embankment is becoming big year by year, and dangers happened frequently.

Flow break – off of the Yellow River began in 1972, and in 27 years until 1998, flow break – off occurred in 21 years at Lijin Station for a total of 1,050 days. The unified dispatching of the stem Yellow River water since 1999 has restricted the tendency of flow break – off, and minimum base flow of 30 m^3/s to 50 m^3/s has kept at Lijin, but inflow into the sea is at a low amount. Without inflow from other basins, water shortage will remain a problem in nature, and the potential and functional break – off will still exist.

In recent years, with economic and social development, pollution sources at both banks are increasing and discharge of polluted water is rapidly rising. As recorded in early 1980s, discharge in the whole basin was 2.17 billion t, and up to 4.35 billion t by 2005, more than doubling that of 1980s. In 2005, the river length of grade Ⅳ water and below Ⅴ water is 54.2% of the evaluated stem river. Water degradation not only directly affects people's life and health, but also less water supply available is further sharpening the water demand and supply conflicts.

4.3.3 Water supplementing in river channel by the Scheme being favorable to maintaining basic channel pattern and healthy river ecology

Water supplementing into the river channel by the Scheme will benefit the joint dispatching and operation of stem river reservoirs and facilitate flow and sediment regulation through the whole river, thus building up a relatively harmonious relationship, gradually enhancing flood – carrying capacity in the main channel of the stem river and reducing sedimentation. As calculated, the first phase will supplement water of 3.5 billion m^3 to the river, and by reservoir regulation, annual sedimentation reduction totals to be 92 million t, and respectively 35 million t, 30 million t and 27 million t in Ningxia to Inner Mongolia, Hekouzhen to Tongguan and lower reaches.

Water diversion of 8 billion m^3 corresponds to additional flow of 254 m^3/s in the stem river, and with a distribution of 3.5 billion m^3 for sediment transport and ecology in the lower channel, including 1 billion m^3 for ecology in non – flood season and 2.5 billion m^3 for sediment delivery in flood season, flow of 48 m^3/s will be added in non – flood season, and 237 m^3/s in flood season. And with reservoir regulation, inflow of over 50 m^3/s is guaranteed at Lijin, flow break – off of the river will be fundamentally resolved, and eco – environment at estuary will be improved.

After water diversion of 8 billion m^3 is supplied to the areas other than the river channel, water volume will add by 7.6 billion m^3, 4.49 billion m^3 and 3.5 billion m^3 at Lanzhou, Hekouzhen and Huayuankou, being equivalent to an increase of observed runoff of respectively 29.9%, 15.5% and 14.8%. The added clean water source will play an active role on diluting of the river pollution, strengthening water environmental capacity of the river, and effectively improving water quality.

Above all, the east, middle and west line projects will concurrently maintain and improve the present water resource distribution pattern, being the strategy that sustainable social and economic development is supported by means of sustainable utilization of water resources. The east and middle line projects will play an active role on maintaining the present water resource distribution pattern, and the west line project will fundamentally improve the distribution pattern of the upper and middle areas, being favorable for maintaining the healthy river. With the east and middle line projects under construction, but for unified resolving of water shortage in the river basin, the west line project should be rapidly implemented.

5 Conclusions

(1) The Yellow River is short of water but laden with sediment, and the two elements act in an unharmonious way, which determines development and utilization of the Yellow River water resources to be carried out by taking care of both the upper and lower reaches and the two bank areas, and coordinating water use for economy and eco – environment in the channel.

(2) Under present conditions, the "87 water distribution plan" is the basis for the Yellow River water distribution. With economic and social development, the situation of water shortage will become severer in the basin, and the east, middle and west line projects are all necessary approaches to maintaining and improving of the Yellow River water resource distribution.

(3) The east and middle line projects will have active effect on the present Yellow River water resource distribution pattern. The west line project will fundamentally improve the present unfavorable pattern in the upper and middle areas and benefit maintaining of the basic channel profile and healthy ecology of the river.

(4) All the trans – basin diversion schemes are favorable to alleviating of water shortage in the basin. For the purposes of resolving water shortage relating to social and economic development in the northwest region, improving and maintaining basic functions of different river reaches and safeguarding of sustainable social and economic development by optimized distribution and sustainable utilization of water resources, the west line project should be implemented as soon as possible.

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Analysis on Contribution and Function of Phase I Works in the West Line of South – to – North Water Transfer Project to National Economy Development

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Abstract: Phase I Works in the West Line of South – to – North Water Transfer Project will divert 8 billion m^3 of water to the Yellow River to raise the water supply guarantee degree for national economy in the target area, and provide an active promotion for the sustainable socio – economic development in the basin and in the ranges. Based on the analysis of current economic status and character of the basin and with the application of integrated analysis model for the harmonious development between water resources and national economy, the contribution and function of Phase I Works in the West Line of South – to – North Water Transfer Project have been hereby analyzed.
Key words: Phase I Works in the West Line of South – to – North Water Transfer Project, Yellow River Basin, economic development, function analysis

1 Economic development status and character in the basin

1.1 Economic development status

The statistical data in 2000 shows that the Yellow River basin has a population of 109. 71 million, or 8. 6% of the total in China, and the urbanization rate is 32. 8% , about 3. 4% less than the average value of 36. 2% in China. The GDP in the basin is 621. 6 billion yuan which is only 7% of the total of the country, and the GDP per capita is about 5,666 yuan which is about 26% less than the average of the country, indicating a relatively lower level of economic and social development in the basin.

The Ningmeng Hetao Plain in upper reaches, Guanzhong Plain and Fenhe Valley in middle reaches, and Irrigation Area in lower reaches in the Yellow River basin make up the important agriculture bases of the country. In 2000, the effective irrigated area of the basin is 75. 63 million mu, the grain output is 35. 31 million t, and the grain output per capita is 323 kg that is 43 kg less than the average of the country. An industrial production layout with perfect structure has been created preliminarily, a set of energy industries, basic industries and new cities have been established, forming a foundation for the further economic development in the basin. In 2000, the gross industrial production value in the Yellow River is 756. 6 billion yuan. Compared with the other areas in the country, the industrial development in the Yellow River still falls behind since the industrial production value per capita is less than the average of the country, and the industry with great water demand and the thermal power industry take a large proportion.

The Yellow River development has relationship with economic and social development in downstream flood control and protection zone. In 2000, the area of downstream flood protection zone is 0. 12 million km^2 , with a population of 87. 55 million, farmland area of 0. 11 billion mu and grain output of 44. 55 million t. It is one of the important bases for grain and cotton production in the country. There are oil, chemical industry, coal and other bases in the zone.

1.2 Economic character

1.2.1 Great contribution of water resources to national economy

According to the input and output table of the Yellow River water resources and econometrics model, the marginal contribution of the Yellow River water resources utilization to national economic development is estimated. In 2000, the elastic coefficient of per m^3 water used for agricultural increased value is 0.254, i.e., the contribution rate of water resources to agricultural increased value is 25.4%, the marginal benefit of agricultural water is 0.69 yuan/m^3; the elastic coefficient of non-agricultural water for non-agricultural increase value is 0.148, i.e., the contribution rate of water resources to non-agricultural increased value is 14.84%, and the marginal benefit of non-agricultural water is 12.01 yuan/m^3. The result shows that the Yellow River water resources has a great function to its economy.

As the Yellow River basin neighbors Huaihe River basin and Haihe River basin, comparisons of them and the whole country in water use benefit are made, shown as Table 1.

Table 1 Comparison of water use benefit of national economy and non-agriculture in some areas

	Area	GDP (10^8 yuan)	Water use (10^8 m^3)	Output rate of per m^3 waster (yuan/m^3)	Elasticiyt of water resources output	Marginal benefit of water use (yuan/m^3)
Total benefit of water for national economy	Yellow River	6,216	386	16.1	0.138,7	2.23
	Huaihe	12,284	555	22.1	0.197,1	4.36
	Haihe	9,470	388	24.4	0.148,1	3.61
	The whole country	82,182	5,183	15.9	0.127,5	2.02
Benefit of water for non-agriculture	Yellow River	4,382	60	81.0	0.148,3	12.01
	Huaihe	9,353	111	83.91	0.183,2	15.38
	Haihe	8,156	75	108.4	0.160,2	17.36
	The whole country	67,274	1,241	54.2	0.136,5	7.40

Note: The data for the Yellow River refer to that for 2000, and the other data are for 1999.

The comparison of water use benefits in national economy shows that both the GDP and water use volume of the Yellow River Basin take the smallest proportion among the three basins, the output rate of per m^3 water and marginal benefit of water use are lower than the other two basins, but slightly higher than the average level of the whole country, and the elasticity of water resources output is lower than the other two basins, but higher than the average level of the whole country. The comparison of non-agricultural water use benefit shows that the output of per m^3 non-agricultural water in the Yellow River basin is obviously higher than the average level of the whole country, and the marginal benefit of water use is 12.01 yuan/m^3, indicating that the contribution of water resources to the non-agricultural production in the Yellow River basin is much higher than the average contribution to the whole national economy.

1.2.2 Lower level of economic development and unbalanced local distribution

In the 20 years from 1980 to 2000, the economic development in the Yellow River basin has lagged behind the average of the whole country, with GDP increase rate of 10.05% which is lower than the average rate 10.76% of the country. The Yellow River basin covers 3 economic zones, the East Zone, Middle Zone and West Zone, and the economic development in each area gets great impact from the economic zone it belongs to. Now, two areas have been established, i.e., the upper and middle reach area mainly for development of agriculture, husbandry and sources, the Lower reach and delta area mainly for process industry. There exists a huge gap between the two areas, for the provinces in the Lower Yellow River basin in the east of the country have a repaid economic development, while the provinces in the upper and middle Yellow River basin in the middle and west of the country have a relatively slow economic development, relying greatly on water resources.

1.2.3 Unreasonable economic structure layout requiring major adjustment

The contrast between a few advanced industries and a large amount of backward industries and between rich areas and poor areas can be found in the basin. The structure among the 3 large industries and within each of them are also not reasonable. The main features are: ① unstable agriculture increase and slow agricultural structure upgrading, low agricultural production rate, heavy task for output and income increase and for internal industrial structure adjustment; ② disharmonious increase between basic industry and process industry, unrelieved restriction on infrastructures and basic sectors, e. g., communication, telecommunication, energy, raw materials, municipal construction, etc.; ③ insufficient third industry quantity that takes a small proportion in the increased value, unreasonable internal structure, lower development level, imperfect social service system for the first and second industries; and ④ lower growth of new and high technical industry that occupies a small proportion in national economy.

The economic development in the basin takes energy and raw material industries as the main, industries with high water demand take large proportion with concentrated distribution. In 2000, the increased value of industry with high water demand and of thermal industry in Yellow River basin takes 34% of the increased value in industry, being 5% higher than the average of the country, in which 50% is contributed by the middle reaches. The current social and economic development status in the Yellow River area can not make full use of the region and resources advantages, and has brought great pressure to water and soil resources and eco – environment, so, the task for industry distribution and structure adjustment is hard.

1.2.4 Rich resource reserves, but limited by water resources

The Yellow River basin is rich in resources, e. g., land, water energy, coal, oil, natural gas, mineral, tourism, etc., especially coal, oil, natural gas and other energy resources have notable advantage. Raw coal output takes over half of the total of the whole country, and oil output takes about 1/4 of the total of the country, which is the largest industry in the basin. Smelting industry of non – ferrous metal, e. g., lead, zinc, aluminum, copper, molybdenum, tungsten, gold, and the rare earth industry have larger advantage, but there is badly lack of water resources. Though the Yellow River is the second largest river in China, its river runoff is only 2% of the total of the country. At present, the occupation of eco – environmental water by economy and living is serious, the healthy life of the Yellow River is threatened, the limited water resources can not satisfy the increasing water demand in economic development, and water resources has become a factor that restricts the economic development in the Yellow River area.

2 Analysis on contribution to economic development by Phase I Works

2.1 Integrated analysis model and research concept for harmonious national economic development

With the application of the integrated analysis model for harmony between water resources and national economic development in the Yellow River basin, the macro economic benefit of diversion scheme is analyzed by the method of "with – without" condition comparison, i. e., analyzing the macro economic effect of each scheme through comparison. That means the scheme without water diversion is defined as zero scheme. Through the comparison of macro economic effects of the water diversion scheme and the zero scheme, the macro impact of each allocation scheme in Phase I Works on the Yellow River economy is assessed.

2.2 Establishment of the Integrated Model

There exists an extremely complicated relationship of mutual promotion and restriction between water resources and national economic development, featuring as spatiotemporal differences. The relationship and character can be described by qualitative analysis instead of quantitative analysis that is so complicated. In order to realize the quantitative research on the harmony between water resources and national economic development, the integrated model, based on a complicated adaptable system theory, is established with the application of a current new technique for water resources research in the world, i. e., integrated model technique. The model can solve the integration problem of routine local model, and through establishing an integrated model frame, it can connect the interaction of each element in water resources system through endogenous variable and realize the uniform of hydrologic modeling and economic optimization.

2.3 Diverted water allocation scheme for model calculation

In order to solve the problems of eco – environmental, living and production water deficit in the Yellow River basin, besides adequate water saving, the West Line of South – to – North Water Transfer Project must be implemented. The target area of the Project consists of the Yellow River basin and the adjacent inland river area, mainly the Yellow River stem course and the areas in the upper and middle reaches, covering 6 provinces (or autonomous regions), i. e., Qinghai, Gansu, Ningxia, Inner Mongolia, Shaanxi and Shanxi. The 8 billion m^3 water diverted through Phase I Works will be allocated in the basic scheme as follows: 3.5 billion m^3 water will be used for recharging the eco – environmental water inside channel in the Yellow River stem including base flow for eco – environment and for channel sediment transport, and 4.5 billion m^3 for the areas outside channel for living and production use of important cities and energy and chemical industry base construction and for important eco – environment construction areas. In the present model calculation, the allocated water volume inside channel has not been considered yet, mainly the schemes of 1 billion m^3, 2 billion m^3 and 3.5 billion m^3 of water allocated outside channel haven been used for the model calculation and analysis.

2.4 Economic development effect of model calculation

The result of model calculation shows that the West Line of South – to – North Water Transfer Project can produce quite notable macro economic effects in any allocation scheme. Under the condition of uniform dispatch of diverted water and the Yellow River basin water resources, taking the scheme of supply 3.5 billion m^3 water to the areas outside channel as an example, in 2020, the GDP in the Yellow River basin can be expected to be 122.3 billion yuan, an increase of 4.77% compared with the condition of having no water diversion, and the benefit of per m^3 water will be 35.0 yuan/m^3. In 2030, the GDP in the Yellow River basin can be expected as 245.2 billion yuan, this is an increase of 4.87% compared with the condition of having no water diversion, and the benefit of per m^3 water will be 70.1 yuan/m^3.

3 Analysis on supporting function to national economy

3.1 Promoting implementation of the west development strategy, and supporting regional sustainable economic development

The Yellow River basin is in the superior geographic position with rich mineral resources and economic foundation, and in the prominent position in the macro productivity layout and regional economic development. The basin includes 3 large zones which are East Zone, Middle Zone and West Zone in the country, covering 7 large economic zones in Around – Bohai Area, North China Area and Northwest Area, meanwhile, Longhai—Lanxin railway and the upper and middle Yellow River range is a Grade I development axis in the ∏ – type point and axis development strategy in the "Outline for Land Planning in China", featuring as advantageous condition for connecting the east and promoting the west, advantage complementation, function harmonization and synergistic development. It is not only a bridgehead and the battlefront in the implementation of West Development Strategy in China, but also the reliable rear.

After the implementation of Phase I Works in the West Line of South – to – North Water Transfer Project, the advantage of the Yellow River flowing thoroughly from the west to the east can lead to development of more energy and mineral resources in the middle and west zones, stable supply of energy and raw materials for the development in the east zone, and can support the sustainable economic development in the east zone. The economic development and the rise of resident income and expenditure in middle and west zones can create a wide product market for east zone and can promote the manufacturing industry development and industry structure upgrading in the east zone. Therefore, the execution of Phase I Works in the West Line can not only promote the implementation of the West Development Strategy, but also support the regional sustainable economic and social development, and it shows a great accelerating function in realizing the total economic development aim in the country.

3.2 Ensuring food security and sustainable agriculture and husbandry development of the country

The Yellow River basin, with broad land area, large amount of farmland resources and proper light and heat condition, is one of the areas which have great potentials for agriculture development. In order to guarantee the food safety of the country, the old irrigation area can be upgraded to raise the grain output of per mu, and part of deserted land proper for farming and large amount of farmland with low and middle output in the Yellow River Basin can provide reliable land resources guarantee for food safety of the country.

The water, after being diverted through Phase I Works in the West Line to the Yellow River, can provide water resources guarantee for the old irrigation area upgrading and new irrigation area development. In case of extremely low flow year or consecutive low flow years, the joint regulation with the reservoirs on the stem both can store the rich flow to recharge the low flow, reduce the eco – environmental water inside channel properly, and increase the production and living water outside channel for a rise of the guaranteed rate of agricultural water supply and rise of the food safety guarantee in the basin.

3.3 Decisive Function to Energy and Industrial Basic Source Production

The Yellow River basin is the most concentrated area of energy and mineral resources, and the heavy industrialization development with resources development and process as the main approaches certainly leads to setting up of a large proportion of energy and raw material industries in this area, forming large amount of energy and industrial basic resources process bases which are in the important strategic positions in the whole country, e. g. , Ningdong Energy Base in Ningxia, Energy and Industry Base in Inner Mongolia, Shaanbei Yulin Energy and Industry Base in Shaanxi, and Liliu Coal and Electricity Base, Linfen New Energy and Chemical Industry Base, and Yuncheng New Energy and Chemical Industry Base in Shanxi. The energy and industry bases hold the important position in the future economic development in the basin and in the West Development Strategy, unfortunately, that is restrained by water resources.

Through the water diversion by the West Line, the energy resources advantage can be used, and this must make a promotion for the repaid economic development in this area. Meanwhile, the output of large amount of energy and raw material products will also provide a strong power for industry development in other areas in the country and accelerate the rising of the adjacent areas and related industries, this will be an active contribution to promotion of the smooth implementation of the West Development Strategy, the sustainable local economic development, and the construction of well – off society all – around, and will play an important role in speeding up the industrialization progress in the country.

3.4 Promoting urbanization progress in the basin

In 2000, the population urbanization rate in the Yellow River is 33% which is lower than the average level in the country by 3%. The cities in the Yellow River basin are mainly arranged along rivers and main access lines, e. g., the city line of Xining—Lanzhou—Yinchuan—Baotou—Huhehaote along Yellow River stem, and the city line of Tianshui—Baoji—Xi'an along Weihe River and Longhai railway line. The radial city circle is developed with central city as the centre, new city and town are set up with new industry base as the core, leading to a larger space for urbanization progress in the basin. But at present, water for cities and towns comes either from over – taking of groundwater or from over – taking of the Yellow River water, it has occupied the water index for other sectors or areas. The speeding up of urbanization and increase of water for city and town will result in more prominent contradiction between the Yellow River water resources supply and demand.

Phase I Works in the West Line of South – to – North Water Transfer Project can supply water to 26 important cities along the Yellow River to basically satisfy the increased water demand at the level of the year 2030, and increase the radial capacity and attraction, and provide water resources guarantee for urbanization progress in the Yellow River. The increase of urbanization rate intensifies the people's living in concentration which is favorable for high – efficient utilization of water resources, it can relieve the eco – environment pressure in a certain degree, especially the agricultural eco – environment pressure, and it is favorable for the efficiency of land resources utilization and the protection of agricultural resources. Meanwhile, the formation of cities is beneficial for radial promotion which is to get enlarged from a point, and for the promotion of economic development in the adjacent areas based on the powerful economic ability of the central city.

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Major Characteristics of West Line of South – to – North Water Diversion Project

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Abstract: The West Line of South – to – North Water Diversion Project, an extra – large trans – basin water diversion project, is a great act for water resources optimizing allocation and an important component of the South – to – North Water Diversion Project. The major Characteristics of the West Line show the rationality and scientificaalness of water diversion from the various aspects, especially the forward looking and adaptability. This article expatiates the necessity and urgency of the project implementation.
Key words: South – to – North Water Diversion, water resources, West Line, major character

Located in the southeast of Qinghai – Tibet Plateau, the West Line of South – to – North Water Diversion Project (referred as the West Line) is at the elevation about 3,500 m. It will divert some water from the upstream of Yangtse River and deliver the water through long tunnel across the dividing ridge Bayankala Mountain to the upstream of Yellow River to make a water source recharge for the Yellow River and the northwest area which are seriously short of water. The West Line features as large scale, great construction difficulty and great function, etc.. Only some of the major Characteristics are discussed in brief hereinafter.

1 Diverting water from humid and semi – humid zone to arid and semi – arid zone

1.1 Geographic condition

The West Line is located in the Southeast of Qinghai – Tibet Plateau, and the diverting works is in the area at the east longitude of 97°30′ ~ 102°20′ and at the north latitude of 31°45′ ~ 33°30′, neighboring Hongyuan of Sichuan at the east, and Jinshajiang River at the west. It is 100 km long from the south to the north, with an area of 30,000 km^2.

The source rivers for the West Line are Daduhe River, Yalongjiang River and Jinshajiang River upstream, and the damsite for water diversion is at the elevation of 3,400 ~ 3,600 m. The areas upstream of damsite are basically shallow – dissected mountain areas at the elevation about 4,400 m where landform is flat, the dissecting is gentle with a relative level drop less than 400 m. The areas downstream of the damsite are basically high mountain areas with medium – dissected wide valley at the elevation of 2,800 ~ 4,500 m where the landform features as rising and lowering with a relative level drop increase and the main river valley is deeply dissected.

1.2 Temperature and precipitation

The precipitation in this area is mainly dominated by monsoon impact, and the annual precipitation decreases from the east to the west gradually. The data from meteorological stations in the adjacent area and from the calculated precipitation shows that the precipitation is nearly 800 mm in the Daduhe Works Area, about 600 mm in Yalongjiang Works Area, and about 500 mm in Jinshajiang Works Area, the annual mean precipitation is 543 ~ 747 mm in which over 50% of the area has a precipitation of 600 ~ 700 mm with a mean value of 653 mm. The precipitation of the 3 source rivers increases gradually to 1,000 ~ 2,000 mm from the upper reach, to middle reach and the lower reach. The annual mean temperature in this area is 2.9℃ ~ 5.6℃.

1.3 Vegetation aridity

Vegetation. Daduhe Works Area has good vegetation and most part of the area is covered with dense virgin forest. In Yalongjiang Works Area, the shady slope of the mountain has forest area and woods area, and the sunny slope is mainly covered with scrub and pasture. Jinshajiang Works Area is mainly scrub, meadow and woods area.

Aridity. This is the index to judge the climate humid degree or draught degree of a region, also referred as moisture index. When precipitation of a region is bigger than evaporativity, it means that the precipitation of this region is surplus when evaporation requirement is satisfied at the same time, resulting in humid climate. Otherwise, the climate is arid. The aridity determination in China is as follows: the area with aridity less than 1 is humid zone, the area with the aridity of 1.00 ~ 1.49 is semi – humid zone, and the area with aridity more than 1.5 is semi – arid zone and arid zone. With the aridity less than 1, the southeast part of Qinghai – Tibet Plateau is in humid zone in China. For more details, Daduhe Works Area is in humid zone, Yalongjiang Works Area is in humid zone and semi – humid zone, the Yushu region in Jinshajiang Works Area is at the aridity of 1.39 and it belongs to semi – humid zone.

Precipitation, vegetation, aridity and some other factors in diverting works area show that the source area belongs to humid and semi – humid zones while the source river sections downstream of diverting works belongs to humid zone with rich water resources. The annual mean runoff in the basin is 60 billion m^3 in Yalongjiang River and 47.5 billion m^3 in Daduhe River. The water volume of the 2 rivers is equal to the water volume of 2 Yellow Rivers. Therefore, diverting water from humid and semi – humid zones to arid and semi – arid zones brilliantly features scientific and rational.

2 Implementation in phases will be practiced as base to realize the general aim of the project

Implementation in phases is an important social practice in human civilization development. The social development, economic development, even a person's development can indicate the importance and necessity of implementation in phases, in stages and in steps. Development is procession, phases are procedures, and they are the expected different aims in tactics to realize the general aim in strategy.

On December 23, 2002, the State Council approved the "General Planning for South – to – North Water Diversion Project", in which the West Line is defined as an implementation in 3 phases. It is planned to divert 4 billion m^3 water from Yalongjiang River and the 5 tributaries of Daduhe River through Phase I Works, 5 billion m^3 water from Yalongjiang River through Phase II Works and 8 billion m^3 water from Jinshajiang River through Phase III Works, the diverted water totals 17 billion m^3. According to the instructions from higher authorities, the plan to combine the phase 1 and phase 2 into single phase have being studied since 2005, and the annual water – transfer volume is adjusted from 9 billion to 8 billion cubic meter to reduce the social and environmental impact.

2.1 Research on feasibility of practical engineering technology shows that implementation in phases is required due to high technical requirement for construction on plateau

As a large – scaled water diversion project, the West Line will deliver water to the upstream of Yellow River through constructing many water – diversion reservoirs and long tunnels of several kilometers, and crossing the dividing ridge Bayankala Mountain. Construction of such a large –

scaled unheard – of project in the southeast of Qinghai – Tibet Plateau is a great challenge. It has a great investment, long construction period and great difficulty in engineering technology. Construction on the Plateau also has some special problems with high requirement for technology, but no previous similar project case can be consulted. Though the current science and technology, especially the long tunnel construction technology, is getting advanced and almost perfect, the Phase I Works of the West Line shall be implemented at first on the basis of the special local natural geographic environment of cold and oxygen deficit, including tunnel about 320 km and several water – diversion projects. This basin – to – basin water – diversion project equals to Yellow River Water Diversion to Shanxi Province in China in terms of project scale. The design and construction experiences coming from the Project will create a sound foundation for the following projects.

2.2 Research on adaptability of practical measures to reduce the unfavorable impacts from diversion on source area shows that implementation in phases is required due to concerned social restriction in source area

From the view of the State's whole strategy, the West Line has a comprehensive and nonreplacable function. As for the source area, the diverted water volume takes up 5% ~ 14% of the source river runoff, which is a small percentage. However, part of water volume under river's natural condition is diverted, resulting in a change of original ecological state of the river. The diverting dam at about El. 3,500 m indicates a water diversion at high elevation which can bring about unfavorable impacts on society, economy and environment production downstream of the project area. The project is in minority area where the Zang nationality is the main people and Zang Buddhism is the common religion. Reservoir will flood a few areas and temples, creating complicated social impacts. Though all the unfavorable impacts are local, from the view of long term, both the serious water shortage in the target area and the benefit in the source area shall be taken into consideration, and measures must be taken to promote the sustainable economic and social development and the sound cycle of eco – environment both in source area and in target area. From the view of coordination and adaptation course of taking measures to reduce the unfavorable impacts on the source area, practical experience for project implementation in phases is required as well.

2.3 Research on forward looking and effectiveness of practical water diversion to Yellow River to reduce water shortage shows that implementation in phases is required due to complication of Yellow River water resources allocation and management

Water shortage in target area and water – taking in source area is a continuous increasing dynamic process. In accordance with the preliminary result in Comprehensive Planning for Yellow River Basin (Range) Water Resources, the annual mean short water volume is 11.64 billion m^3 in 2020 level year and 14.56 billion m^3 in 2030 level year in Yellow River Basin. Obviously, water shortage is a gradually increasing process, so is diverted water volume. The rather that, quantum method is adopted for short water volume prediction, and the short water volume is obtained through deducting the available supply water volume in the region from the sum of water demand for comprehensive production, living and eco – environment. Because the prediction involves many factors which are unfixed, the prediction for water demand volume may have error. From the view of process of increasing water demand and water diversion, practical experience for project implementation in phases is required as well.

The water diverted through the West Line is delivered to Yellow River upstream and Yangtse River water is mixed with Yellow River water, new mechanism and system shall be taken for the overall dispatch and management of Yellow River water resources and for optimizing allocation of water resources, and reasonable water price system shall be established to promote water – saving. And there shall be much auxiliary project construction, or the diverted water can not be used in some places. The complication of Yellow River water resources allocation and management and the difficulty of auxiliary project construction show that practical experience for project implementation in phases is required.

It can be seen from the above that with the principle of "from the far to the near and from the easy to the difficult", the West Line can solve the problem of water shortage in Yellow River and in Northwest Area step by step through overall planning, in – phase implementation, gradual enlarging of diverted volume, scroll development and timely adjustment for the purpose of keeping the forward looking and continuity.

3 Target area is the whole Yellow River Basin, water diversion and use at high elevation will be the main purpose

The diverted water into the Yellow River through the West Line features as: ①the target area is the whole Yellow River Basin with a broad coverage; ②water diversion and use at high elevation will be the main purpose.

3.1 Target area is the whole Yellow River with a broad coverage

Water can be diverted to Yellow River headwater section through the West Line, and flows through Yellow River course which runs from the west to the east in China. Through the regulation and storage of some large – scaled reservoirs in the upper reach of Yellow River, such as Longyangxia and Liujiaxia, etc., part of water can be allocated and supplied for the water and sediment regulation system in the middle reach from high elevation to the low elevation to make an active function of creating ideal water – sediment process.

3.2 Water diversion and use at high elevation will be the main purpose

The diverted water through the West Line will enter the Yellow River course at El. 3,442 m. This is the only water source coming from other basin into the center of northwest inland area. In order to make full use of the water diverted at high elevation, water is supplied to the areas, Qinghai, Gansu, Ningxia, Inner Mongolia, Shaanxi and Shanxi which are seriously short of water and to the inland river area in Hexi Gallery for water recharge below El. 3,000 m in the middle reach of Yellow River. The high elevation and broad area of water supply is the scarce and great Characteristic in West Line. With the consideration of developing the land resouces, rich mine resources, oil and chemical industry resources and other energy resources in the broad northwest area and promoting the rapid economic and social development in the area, water diversion and use at high elevation shall be the main purpose, i. e., recharging water source to the target area in northwest in China shall be the main purpose.

South – to – North Water Diversion Project consists of the West Line, Middle Line and East Line. The Middle Line and East Line cross Yellow River as a crossing intersection at El. 109 m and El. 43 m, and supply water to big cities in the west and east of Huabei Plain. The general layout for the West Line, Middle Line and East Line corresponds to the 3 ladders in the topography in China which are Qing – Tibet Plateau, Loess Plateau and Huabei Plain, i. e., water diverted at high elevation is used in the areas at high elevation and water diverted at low elevation is used in the areas at low elevation. This reasonable layout is adaptable for each Line. The 3 Lines can form a general layout to mitigate the water shortage in the North of China. The 3 Lines have interrelationship and each has its main aim and scope for water supply. They can supplement each other but not substitute each other.

4 Yellow River water sources recharge through diversion shall base on precondition of intensifying water – saving and full utilization of local water resources in target area

The West Line is planned in 3 phases, and the Phase III Works will be completed before

2050. The diverted water volume to Yellow River will be 17 billion m^3 in total, which can increase water volume by almost 1/3 of the Yellow River annual mean runoff 58 billion m^3. This can make up for the insufficiency of Yellow River basin water resources, improve water supply condition, and basically resolve the water shortage problem in future 50 years. Broadening source and saving expenditure is the broadening source on the basis of saving expenditure. Water diversion can only recharge water source. Water source recharge has two preconditions, the first is to intensify water saving and construct water – saving society, the second is to make full use of the local resources and raise water utilization efficiency.

4.1 Intensifying water saving

The basic measures to mitigate the water shortage in Yellow River basin are to intensify water saving and construct water – saving society. The analysis shows that the water volume saved in 2030 will be 7.8 billion m^3 under the thorough development of water saving potential. The implementation of this water saving aim shall be guaranteed by engineering and non – engineering measures, especially by carrying out the Rules for Yellow River Water Dispatch issued by the State Council in 2006. Constructing water – saving society is a great systematic project, and reasonable replanning for water resources development, utilization and allocation shall be made, and measures shall be prepared to realize the above mentioned water saving · Otherwise, the situation of water shortage will be worsen.

4.2 Full use of local water resources

In order to realize the sustainable development in the northwest area, a series of changes are required in water resources development mode. The productivity layout, industry structure and development mode shall be adjusted. Water demand shall be ascertained on the basis of supply capacity, water shall be the basis for decision, including regional development scale, water resources and land development and utilization, eco – environment protection scale, and forestation. Raise water use efficiency, strengthen reuse of treated wastewater, use rain water resources, exploit groundwater reasonably, and make full use of local water resource.

5 Recharging eco – environmental water for Yellow River in target area, protecting and improving eco – environment

5.1 Environment problem in Yellow River and in northwest area

Because of the dry climate and long – term human activity impact, the water – taking in Yellow River basin surpasses the bearing capacity of Yellow River water resources, and eco – environment is badly damaged while keeping the economic and social development. This is reflected in concentration as follows: outside river course, lake shrinking, enlarging of groundwater depression area, vegetation degeneration, increase of hungriness, frequent sandstorms, disappearing of human living condition in some areas and appearing of "eco – environment refugee" in these areas; inside river course, riverbed rising by deposition, appearing of "suspended river" in upper Ningmeng river reach, increase of transverse gradient of lower reach "suspended river" course, accelerating of "secondary suspended river", water body pollution, etc. All these create a threat to human living environment.

5.2 Recharging eco – environmental water for Yellow River and northwest area

Insufficiency of water is the primary source for the worsening of Yellow River water environment and northwest eco – environment, therefore, eco – environment protection and recovery focuses on water. After the operation of the West Line, part of the allocated water volume will recharge eco –

environmental water for northwest area and Yellow River course. The recharging of eco – environmental water consists of 2 modes, and it can act both for long term and for emergency.

Implementation of the West Line can recharge water source for long term historically. In a certain range and degree, it can hold back the course shrinking of Yellow River and land desertification in northwest area, remedy the damaged eco – environment, recover and establish new ecosystem, raise the bearing capacity of Yellow River water resources, keep the healthy life of Yellow River, upgrade the environment capacity in northwest area, and realize the harmony between human and water.

The implementation of the West Line can recharge water source emergently for rescue. In the case of dry natural geographic climate in northwest area, draught appears frequently with long lasting duration and large impacted range, resulting worsening of eco – environment and great harm. Lasting extraordinary draughts occurred in history, and many people died of hunger. Based on the Statistics from 1951 to 1999, the frequency of draughts in northwest area is about 60%, there are 6 to 8 dry years in 10 years in the middle and north of Gansu and in Ningxia, extraordinary dry years will be 1 of 2.5 ~ 6.5 years. The draughts in northwest area are related to the consecutive dry years. The measured data show that there were 2 consecutive 11 – year dry durations from 1922 ~ 1932 and from 1990 ~ 2000 in Yellow River, and the northwest area met with draughts in various degrees. When the West Line which is the only approach to deliver water to Yellow River is completed, it can recharge water source for emergency and serve for eco – environment for rescue when a draught in a certain area has impact on human living environment and when zero – runoff appears in the lower reach of Yellow River.

6 Conclusions

The West Line has characteristics as follows: Water is diverted from the humid and semi – humid zones upstream of Changjiang River with rich water sources to Yellow River and the northwest arid and semi – arid zone where water is severely short; The project is implemented in phases; Target area is the whole Yellow River basin and water diverted at high elevation is used in the area at high elevation; Yellow River water sources recharge through diversion bases on preconditions of intensifying water – saving and full utilization of local water resources; Recharge eco – environmental water for Yellow River target area. It can be seen from different aspects that the West Line is a large – scaled project with great benefit, special environment and complicated technology and the implementation of the West Line is not only scientific, reasonable, and necessary, but also imperative and quite urgent under the situation. In general, the West Line of South – to – North Water Diversion Project, a huge trans – basin water diversion project, is a great act for water resources optimizing allocation, an important water supply project and an eco – environmental project. It is the important infrastructure to support the implementation of West Development Strategy and to support the sustainable economic and social development on the basis of sustainable utilization of water resources, showing the scientific development and the concept of harmony between human and the nature. The preparation work for the West Line is now under promotion, and the great effort is made to commence Phase I Works of the West Line after 2010.

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Methods to Reduce Unbalanced Water Quantity in the Lower Yellow River

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Abstract: Water interception has not occurred in the lower Yellow River in recent seven years because of the overall regulation since March, 1999. However, data analyses indicate that severe water unbalance exists in the lower Yellow River, which is worsening with the increase of water diversion. Through the analysis of major reasons of water unbalance, the author believes that the main methods to reduce the water unbalance in the lower reaches are to strengthen management in water diversion monitoring, to make reasonable water taking rules in floodplain and to severely punish irregular water diversions against law.
Key words: water dispatching, water loss, water resources, channel, the Lower Yellow River

Since overall water regulation was carried out in the Yellow river in Mar., 1999, trend of increasing water use has kept down and contradiction arisen from the water use has been relieved Furthermore, water interceptions in the provinces along the Yellow River did not occur in recent seven years, eco – environment in the estuary is stepping into optimal circle, the social and economic benefits are very remarkable. But the differences of water balance in the lower Yellow River are very high for some reasons; with the maximum difference of more than 5 billions m^3 (excluding natural loss of the rive channel), which is about 9% of the nature runoff from the Yellow River. Large water losses make water resources scarcity more serious and the water dispatching more difficult.

1 Unbalanced water quantity in the Lower Yellow River

1.1 Calculation methods for channel water quantity balance

Water balance is a form expressing the principal of mass conservation in hydrology, by wording it means that the difference between input and output of water to a region at any time equals the water storage change within that region at that period, which can be expressed by:

$$W_{in} - W_{out} = \pm \Delta W \qquad (1)$$

where, W_{in} and W_{out} Wout are input and output water respectively; ΔW denotes the change of water storage in the unit of $1 \times 10^8\ m^3$.

Major reaches from Xiaolangdi Reservoir to Lijin are so called "suspended river", their water balance factors are: up – section input runoff (W_{in}), down – section output runoff (W_{out}), water added in – between (W_{sec}), evaporation (ω_{eva}), leakage (ω_{leak}), industrial and agricultural water use (W_{use}). The water balance equation of the lower Yellow River can be built as

$$W_{out} = W_{in} + W_{sec} - W_{use} \pm \Delta W - \omega_{eva} - \omega_{leak} \qquad (2)$$

In fact, water balance in the lower Yellow River can not be calculated correctly using the equation above. In order to keep the water balance, an unnatural water loss (ω_{loss}) should be included in the equation:

$$W_{out} = W_{in} + W_{sec} - W_{use} \pm \Delta W - \omega_{eva} - \omega_{leak} - \omega_{loss} \qquad (3)$$

1.2 Water unbalance in the Lower Yellow River

The mean annual unbalance water in the Huayuankou and Lijin reach from 1999 to 2005, revealed by the hydrologic statistics, is about 4.3 billion m^3, which is one fifth of the average runoff from Huanyuankou section. Except for the deducted 1 billion m^3 water because of channel evaporation and leakage, there is 3.3 billion m^3 unbalance water. In spatial distribution, about 90% unbalance water centers on the reaches outside Jiahetan—Gaocun; whereas, in temporal distribution, about 70% unbalance water emerges in the months of March, April, May and September. The law shows that unbalance water would increase with the more water diversion, and decrease with the less water diversion. For example, in the year 2002 when the maximum water was diverted since the overall regulation of the Yellow River, unbalance water was 1.45 times of the annual mean from 1999 to 2002; however, the unbalance water in 2003 was only 0.7 times of the annual mean, because that water diversion from April to June of 2003 was the minimum for the great drought of the Yellow River.

2 Reason of unbalanced water

2.1 Nonstandard water diversion monitoring

In most case, nonstandard monitoring makes observation value lower than actual value. The analysis on sync monitoring data from the culverts and gates of the Yellow River indicates that system error of water diversion monitoring changes are in the range of 4.5% ~ 33%, average is 15%. The prim reasons are listing below:

(1) Incomplete water monitoring facility and nonstandard using. First, in most water gate measuring section, no star or end pile is set up and the zero points of measuring are unfixed. Comparing measure indicates that the maximum system error caused by unfixed zero point is 3.5 m and the minimum 1.4 m. The second, most echo devices of elliptical type weight is out of work. Technicians depend on their experiences to judge whether elliptical type weight touches the river ground, so the measuring precision is lower. Percentage of pass for water depth measuring in a water gate is only 42%, and the measuring error of single pivot point is -20 cm. The third, use of current meters is not to the standard. Comparing runoff using current meter does not accord to River Flow Measuring Standard (GB 50179—93).

(2) Methods to measure and calculate flow are nonstandard and calculated error ratio is high. First, vertical plumbs for measuring flow velocity and depth are inadequate in most of the measuring sections. Especially, in the main channel and near river banks where the water depth and velocity change abruptly, vertical plumbs are arranged less, which can not control the main turning points of flow and land form distribution. Second, the number of speed measuring point is less. Finally, the first-hand measuring results can not be detected and measuring error can not be corrected in time. In some water gate stations, the relation curves between water level and runoff have not been calibrated for many years as well as comparing calibration between upward and downward water level. In some other culvert stations, "three-time-detection" procedures are omitted completely, as the results, error ratios in some stations are very high, even get to 25%, single runoff error gets to 5.9 m^3/s.

2.2 Exclusion of uncontrolled water diversion at floodplain and river works

The floodplain in the lower river is very vast, which is 84% total channel area of the lower Yellow River. With the support of special funds for national comprehensive development, the hydraulic engineering construction of three phases had been implemented from 1988 to 1996. Effective farmland and water taking facilities all increased rapidly, the water demand are also gradually increasing, especially in the water using peak time (Mar. to May), lots of water taking facilities or temporary water pumps can be seen in lower Yellow River. So the accumulative water diversion is very large. An overall survey by YRCC in Apr. , 2001 shows that the water taking flow in the survey day is 110 m^3/s. Considering the irrigation habits of each floodplain and actual survey results, the mean annual water consumption calculated by "Area - quota method" is about 0. 6 billion m^3. Moreover, part of water consumed by barrier reinforcing engineering can not be included in the water assumed by . Henan and Shandong provinces.

2.3 Water leakage and stolen events of individual stations

Water diversion culverts and gates in the lower Yellow River were built in different years, water leakage is still occurring though most of these hydraulic works were repaired or rebuilt later. In some gate stations, small streams can be seen at downward side of culvert gate by video monitors set in YRCC Water Dispatching Center, while the water gates is closed, the maximum detected water leakage is about 4 m^3/s. Moreover, water stolen events sometimes occur in a few stations. Means of stealing water is very superb. Some gate stations steal water in the evening and close anchor gates at daytime; some gate stations divert water according to water using plan at daytime and beyond the plan in evening; the worst is some culvert gates report false amount of water diversion, for instance, one water gate only reported about 30% of its actual water diversions for a year time; some culvert gates divert water according to water using plan before they report water diversion flow and later divert water far above the plan. All of these has aggravated the water unbalance of the lower Yellow River.

3 The main way to reduce water quantity unbalance

3.1 Implement Hydrological Act of the People's Republic of China and intensify management and monitoring to water diversion culvert gate

The activity of channel flow monitoring is within the scope of hydrology monitoring, so it should obey the provisions of Hydrological Act of the People's Republic of China (following shortened as "Act"), carry out the monitoring activity according to national hydrology standards, criteria and regulations, intensify the management and monitoring to water diversion culverts and gates, and accept the direction from hydrologic agencies directly under the water conservancy administrative department, so as to improve the monitoring accuracy of water diversion culvert gate and reduce water loss.

(1) Unify and formulate the renewal and modernization plan for monitoring facility and equipment of culverts and gates. It is stipulated by Article 19 of the "Act" that the equipment for hydrology monitoring should confirm to the technical requirement according to the provisions of the water conservancy administrative department under the State Council, the measurement instrument for hydrology monitoring should be examined and pass the inspection according to law. The provisions mentioned above shows the importance of equipment and instrument to hydrology monitoring. With regard to the problems existent in the equipment of the Yellow River water diversion culvert gate, it is suggested the relevant department, together with the specialty department, to inspect the monitoring equipment and instrument of culverts and gates, classify the unqualified equipment, and put forward the monitoring plan and updating proposal according to the outflow condition, flow and gate style, gradually standardize the equipment and instrument for hydrology monitoring, so as to make it confirm to the technical requirements of the State.

(2) Calibrate the flow computation curve of culverts and gates at a fixed period. The channel of the Yellow River is movable, and the water is diverted from the side of the river by gates that significantly influences the scour and siltation of the section by gate opening and closing. It destines to affect the accuracy of flow computation if the stage - discharge curve is not modified according to the variation of scour and siltation of the cross - section. By data analysis of Weishan gate, during the period of transfer water from the Yellow River to Tianjin in 2002, it transferred water to Tinjin

for 85 days, calibrated 29 flow computation curves and plotted 75 flow computations time period, as a result, it controlled the stage and discharge process very perfectly. It shows that the flow computation curve of culvert gate is variable, and it needs a real – time adjust according to the variation of scour and siltation of cross – section. Actually, it is not necessary to real – time adjust the flow computation curve for a culvert gate, it proposes to calculate the flow computation curve by authorized agency just in spring and autumn before water diversion.

(3) Training the technicians on regulation and monitoring capacity. The main reason for lots of error and low accuracy, besides the problem of hardware, lies in that the operators' technical level couldn't meet the basic requirement, and their consciousness of implementing hydrology criteria and regulations on working need to be raised. In this regard, it suggests that the relevant departments should intensify the operators' study on hydrology regulation, criteria, and survey knowledge, invite experts to provide technical training to operators, and build a strict check – on work system, so as to improve the survey accuracy and technical level.

3.2 Normalization management on taking water of the floodplain, water consumption accounts to the water quota of their provinces

The floodplain in the lower Yellow River is 3,544 km^2, covering 15 cities and 42 counties of Henan and Shandong provinces, with plough land of about 3,340,000 mu. By statistics, there are 916 water taking facilities (including water diversion gates, fixed pumping stations, pumping boats and temporary pumps, etc.), with the equipment of 17,876 sets, having the total water diversion capacity of 547 m^3/s. At present, there are more than 1,800,000 people living in the floodplain, the water consumption by industry and domestic is very high, with seasonal and movable characteristics, so it is very difficult to measure the actual water consumption. However, it could classify and manage them. For the fixed water taking facilities, it is better to manage them by issuing license for water drawing, manage their water use with order, and dispatch water as culvert gate of the Yellow River, in the same time it carries out daily (weekly or half monthly) report of water drawing; for the movable pump stations, develop patrolling and inspecting every day, investigate the number of running pump stations and their working times, so as to calculate the water diversion amount, report the total water drawing amount every ten days to the management department, to ensure the management department have a comprehensive grasp of the variation of water amount in the Yellow River.

3.3 Implement effective supervision and inspection, severely punish the case of drawing water against rules

Supervision and inspection on water use is essential to ensure the implementation of water dispatch, and it only works on the premise of effective supervision and inspection. It is proved by practices that spot check is the most effective way since it could get the real finding in the case of the object checked without any preparation. Since the implementation of united water dispatching, many cases such as excessive drawing water over and above the quota, furtively, and drawing more water but report less, were found by spot check. Because there are not corresponding punishment measures, the departments and unites who have found against the drawing water rules are reluctant to correct. On August 1, 2006, the Ordinance on Yellow River Water Volume Regulation promulgated by the State Council, was put in force, which stipulates that unites of drawing water exceeding the quota should be responsible for legal liability as well as the corresponding responsible person. It proposes the relevant departments and unites execute effective supervision and inspection, severely inspect and frighten the cases of against drawing water rules, so as to reduce water unbalance caused by human activities and protect water resources.

Preliminary Study on Water Allocation in South – to – North Water Diversion Project

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Abstract: Based on the characters of the Yellow River basin water resources and the layout of future economic and social development and with the comprehensive consideration of the eco – environmental water demand to keep the healthy life of the river, the situation of future water resources supply and demand in the Yellow River basin and water shortage state is analyzed, and the target area limit and supplied sectors of the West Line of South – to – North Water Diversion Project are determined. In accordance with principle of people oriented, harmony between human and nature, and high – efficient and sustainable utilization of water resources, the allocation scheme for the water diverted through the West Line of South – to – North Water Diversion Project is proposed and the function and benefit from water diversion is analyzed to provide technical support for the decision – making and implementation of the West Line of South – to – North Water Diversion Project.

Key words: the West Line of South – to – North Water Diversion Project, target area, water resources allocation

1 Analysis on state of the Yellow River Basin water resources

1.1 Water resources volume and change trend

The Yellow River resources features as shortage in total volume, unbalanced spatio – temporal distribution, difference sources for water and sediment, consecutive draught, alternatives of rich and low flows, etc.. In the recent 20 years, because of the development of agricultural production, construction of eco – environment for water and soil conservation, rainfall collection for use and development of groundwater, etc., the underlying surface condition is changed, leading to an obvious variation of precipitation – runoff relationship, and notable less river runoff than before under the same precipitation condition, especially in the middle reach of the Yellow River. The analysis shows that the annual mean precipitation in the Yellow River in the 45 – year series from 1956 to 2000 is 447 mm, the natural annual mean runoff at Lijin Gauging Station is 53.5 billion m^3, which is 4.5 billion m^3 less than the 58 billion m^3 in the 56 – series from 1919 to 1975. The decrease of water resources volume resulted from the change of underlying surface condition is an unconvertible change in trend, leading to further decrease of the Yellow River basin water resources. It is predicted that the runoff at the level in the year 2030 will further decrease by 2 billion m^3, and the corresponding natural runoff will be 51.5 billion m^3.

1.2 Water resources demand

1.2.1 Prediction of water demand from economic and social development outside channel

The Yellow River basin is rich in energy and mineral resources, but the current economic and social development is relatively backward, indicating a great development potential in the future. The strategies of West Development and accelerating the uprising of the Central Region in China and the great target to construction affluent society which are proposed by the State will all make a great promotion for the healthy, rapid and sustainable economic and social development in the upper and middle reaches of the Yellow River. It is predicted that the GDP at the level of the year 2030 in the Yellow River basin will be 7,350 billion yuan, the increased value of common industry will be 2, 273.1 billion yuan, the installed capacity of thermal power plant will be 157.31 million kW. Meanwhile, the Yellow River basin has a long history of the agriculture development and is an important agriculture base in China which takes the important position in production scale and capacity in agriculture and animal husbandry. The prediction shows that the irrigated field area in the Yellow River basin will increase to 86.52 million mu in 2030 from 75.63 million mu in 2000, and the pasture area will increase to 11.93 million mu in 2030 from 7.56 million mu in 2000. The rapid economic and social development will certainly need the support of more water resources, and the actual water volume which was used in 2000 in Yellow River basin is 50.68 billion m^3 (including 8.8 billion m^3 supplied to the outside of the basin). In the prediction, with the comprehensive consideration of water saving, the water demand from economic and social development at the level of the year 2030 will be 64.7 billion m^3 (including 9.9 billion m^3 supplied to the outside of the basin), with the details shown in Table 1. The increase of water for national economy mainly comes from the increase of municipal living water and industrial water which is closely related to the continuous city enlarging, industry structure character and rapid development in the basin, etc., while the water demand from agriculture decreases.

1.2.2 Prediction of water demand from eco – environment inside channel

The Yellow River is a river with a higgest sediment content in the world, the annual mean sediment discharge is as high as 1.6 billion t. For a long time, large amount of eco – environmental water is used up by others, leading to a series of problems which threaten the river health, e.g., a sharp decrease of water inside channel, zero – flow in river course, riverbed rising, worsening of water quality, etc.. Therefore, in the allocation of the Yellow River water resources, eco – environmental water demand must be taken into consideration, including water for the sediment transport in flood season and the eco – environmental base flow in non – flood season, etc., and the economic and social development must base on the precondition of keeping the healthy life of the Yellow River. At present, the river sections with heavy deposition and great risk of flood on the stem are Downstream Section and Ningmeng Section, and analysis focuses on the eco – environmental water demand from the two sections as a result.

Table 1 Water Demand outside Channel in the Yellow River Basin

Unit: $10^8 m^3$

River section	Living	Industry	Agriculture	Eco – environment	Total
Upstream Longyangxia	0.2	0.1	3.4	0	3.7
Longyangxia to Lanzhou	3.9	17.2	29.0	0.6	50.7
Lanzhou to Hekouzhen	7.4	27.2	169.2	3.5	207.4
Hekouzhen to Longmen	3.1	10.4	15.8	0.4	29.8
Longmen to Sanmenxia	22.4	41.8	91.5	1.9	157.6
Sanmenxia to Huayuankou	6.2	15.5	18.5	0.5	40.7
Downstream Huayuankou	5.1	10.4	35.9	0.3	51.7
Inland area	0.2	0.8	5.0	0.2	6.2
Sub – total in basin	48.7	123.4	368.3	7.4	547.8
Sub – total outside basin	0.0	19.3	74.0	6.0	99.3
Total	48.7	142.7	442.3	13.4	647.1

(1) Water for sediment transport in flood season

Based on the long – series water and sediment data and with the consideration of inflow from tributaries and the water and sediment taking along the Yellow River, water for sediment discharge in flood season is analyzed for Ningmeng Section and the Downstream Section.

Based on the analysis, the in – sediment at Balangao Station in Ningmeng Section is 0.112 billion t, under the condition of annual mean deposition at 46.5 million t in section from Bayangaole to Hekouzhen, the water for sediment at Hekouzhen section in the whole year shall be 23.2 billion m^3, including 12.7 billion m^3 in flood season. Under the condition of downstream in – sediment at 1 billion t, the water for sediment transport in flood season at Lijin shall be 15 ~ 17 billion m^3 in order to keep the downstream deposition rate at 20% ~ 25%, i. e., annual mean deposition at 200 ~ 250 million t; the water for sediment transport at Lijin Station in flood season shall be 24.8 billion m^3 in order to keep the balance of downstream deposition.

(2) Eco – environmental base flow in non – flood season

Analyzed from the aspects of ensuring no zero – flow at estuary, maintaining wetland in estuary delta, and water for neritic organism and sight at estuary, etc., the eco – environmental water demand in non – flood season at Lijin Section shall be about 5 billion m^3. Analyzed from the aspects of maintaining the basic function of river course in Ningmeng Section and Xiaobeiganliu, and ice – jam control in Ningmeng Section, etc., the eco – environmental base flow in non – flood season at Hekouzhen Section shall be 7.7 billion m^3.

1.3 Situation of water supply and demand

The Yellow River is poor in water resources and the contradiction between supply and demand is serious. Based on the 45 – year natural runoff series from 1956 to 2000, the balance on the Yellow River water sources supply and demand is conducted according to the demand and available water volume at the level of the year 2030, the result is shown as Table 2. At the level of the year 2030, the annual mean national economic water demand outside channel in the Yellow River basin and the related areas is 64.7 billion m^3, the water supply is 53.8 billion m^3, the water shortage is 10.9 billion m^3, and the water shortage rate is 16.9%; the eco – environmental water demand inside channel is calculated as 22 billion m^3, and the water shortage is 4 billion m^3; and the water shortage both inside and outside channel totals 14.9 billion m^3. The areas with water shortage outside channel are concentrated in the range from Lanzhou to Hekouzhen at first, with a total water shortage of 4.9 billion m^3, covering 44.4% of the water shortage outside channel; Some areas with water shortage are in the range along the tributaries of Fenhe River and Weihe River from Longmen to Sanmenxia, with a water shortage of 2.8 billion m^3, covering 25.7% of the water shortage outside channel. The range from Longmen to Sanmenxia features as water shortage in Weihe and Fenhe river basins, with the shortage of 1.9 billion m^3 in Weihe and the shortage of 0.9 billion m^3 in Fenhe.

It can be seen that with the rapid economic and social development, the water shortage in the Yellow River in the future will being getting more serious, and diverting water from other basin to recharge the total the Yellow River water resources can support the sustainable economic and social development in the areas along the Yellow River and keep the healthy life of the Yellow River itself. In the layout of economic and social development and the distribution of water shortage area, the energy bases and cities which will have the most rapid development in the future in the basin are concentrated in the upper and middle reaches of the Yellow River, which is the area short of water in concentration. Therefore, only the implementation of the West Line of South – to – North Water Diversion Project to comprehensively resolve the problems in water supply in upper and middle reaches on both sides of Heishanxia Section, and problems in water demand inside channel in Hexi inland rivers and the Yellow River can best solve the problem of the Yellow River water shortage.

Table 2 Balance of Water Resources Supply and Demand in the Yellow River Basin

Unit: $10^8 m^3$

River section	Level in 2030		
	Demand	Supply	Shortage
Upstream Longyangxia	3.7	3.6	0.1
Longyangxia to Lanzhou	51.1	40	11.2
Lanzhou to Hekouzhen	215.0	166.5	48.6
Hekouzhen to Longmen	35.40	32.55	2.85
Longmen to Sanmenxia	157.6	129.5	28.2
Sanmenxia to Huayuankou	41.4	39.0	2.5
Downstream Huayuankou	136.7	121.9	14.8
Inland area	6.2	4.9	1.3
Sub – total inside channel	647.1	537.9	109.5
Sub – total outside channel	220.0	180.0	40.0
Total	867.1	717.7	149.4

2 Allocation scheme for diverted water

With the comprehensive consideration of the Yellow River water resources character, water shortage area distribution and feature, water supply efficiency and benefit, and difficulty for water use, etc., it is determined preliminarily that the water supply scope is the whole Yellow River basin and the adjacent Hexi inland area, the supplied water includes the eco – environmental water inside the Yellow River channel, the water users are the cities, important energy bases and ecologic zone, etc..

2.1 Allocation principle

Because of the poor water resources and the water deficit in the Yellow River basin, the gap between water resources supply and demand is still large under the condition of full consideration of water saving. Since the water diverting scale in the West Line of South – to – North Water Diversion Project is limited, in order to make full use and benefit of the diverted water, the diverted water is allocated in accordance with the principle of uniform dispatch and management of the Yellow River water resources to solve the urgent and key problems in sustainable development in the Yellow River basin or in the adjacent area and to relieve the water resources deficit in the target area at maximum. Allocation of the diverted water shall obey the following principles:

(1) Comprehensively considerate the production and living water outside channel and eco – environmental water inside channel, satisfy the lower limit for eco – environmental water demand of river, show care for economic benefit, social benefit and eco – environmental benefit;

(2) Comprehensively considerate the water utilization requirement of various river sections, provinces and sectors, both consider the water deficit degree of each region and sector and consider water supply efficiency and benefit based on the principle of fair, high – efficient and sustainable use. Preferentially satisfy the water demand from living, heavy industries and energy bases;

(3) Comprehensively allocate the water resources of stem and tributaries, incarnate the principle of water diversion and use at high elevation. Under the precondition of considering the eco – environmental water inside channel, tributaries can use the local water preferentially, the increased water supply from the West Line recharge the reduced water volume of the stem.

2.2 Allocation scheme

According to the determined target area and served sector and based on the available water diverted through the West Line of South – to – North Water Diversion Project, study on several allocation schemes is carried out in accordance with various diversion volumes, various allocation proportion inside and outside channel, and various served sector outside channel, etc. In this article, analysis is carried out with diversion volume of 8 billion m^3, allocated water of 3.5 billion m^3 inside channel and allocated water of 4.5 billion m^3 outside channel as the representative scheme, and the result is shown as Table 3.

Table 3 Allocation Scheme for the Diverted 8 billion m^3 outside Channel

Unit: $10^8 m^3$

Served sector	Allocated volume
Important cities	20.7
Energy bases	12.5
Heishanxia Eco – environment Zone	7.8
Hexi inland rivers	4.0
Total	45.0

2.2.1 Allocated water inside channel

The 3.5 billon m^3 water allocated inside channel in the Yellow River stem will mainly recharge for the reduction of natural runoff and insufficiency of eco – environmental water at lower limit. On the basis of ensuring no zero – flow in the Yellow River stem channel, create a reasonable water – sediment process through the joint regulation of the key projects on the Yellow River stem, e. g., Longyangxia, Lijiaxia, Heishanxia, Guxian, Sanmenxia, Xiaolangdi, etc., to relieve the deposition in Ningmeng Section, Xiaobeiganliu and Downstream Section of the Yellow River.

2.2.2 Allocated water outside channel

In the allocated 4.5 billion m^3 water outside channel, 2.07 billion m^3 is supplied to more than 10 cities in the basin, e. g., Xining, Lanzhou, Baiyin, Yinchuan, Baotou, etc., 1.25 billion m^3 is supplied to energy and chemical industry bases, e. g., Ningdong in Ningxia, Shaanbei in Shaanxi, Erdos in Inner Mongolia, Liliu in Shanxi, etc., 0.78 billion m^3 is supplied to Heishanxia Eco – environment Zone, and 0.4 billion m^3 is supplied to Hexi inland river. From the view of supplied sectors, water supplied to cities and energy and chemical bases takes 74% of the total water volume outside channel, including 46% for cities and 28% for bases, and this will provide great support for the West Development and promote the regional sustainable economic and social development in northwest area. The water supplied to Heishanxia Section of the Yellow River and Hexi inland rivers takes about 26%, and this can provide proper condition to recover and improve the regional eco – environment and to throw away poverty.

3 Preliminary analysis on water diversion function

3.1 Increasing water volume for national economy, effectively relieving contradiction between water resources supply and demand, supporting sustainable economic and social development

Firstly, Guarantee the water supply for living: Based on the analysis, 2.07 billion m^3 water from the Phase I Works in West Line shall be supplied to the important cities, and most of the newly increased water demand at the level of the 2030 can be satisfied, and this can provide water resources for urbanization progress in the Yellow River basin; 780 million m^3 is supplied to the area adjacent to Heishanxia, this can improve the local drinking water condition from the root, solve the problem about drinking water for people and livestock and remove disease induced by fluorine; 400 million m^3 is supplied to the downstream of Shiyanghe River in northwest area, this can improve the local drinking water condition and guarantee the drinking water safety of people and livestock while improving the local eco – environment state. Secondly Guarantee water for heavy industry: 1.25 billion m^3 water is supplied to the energy and industry bases, including Ningdong in Ningxia, Erdos in Inner Mongolia, Shaanbei Yulin in Shaanxi, Liliu in Shanxi, etc., this can basically satisfy the newly increased water demand at the level of the 2030. Raise guaranteed rate of agricultural water supply: supplying water to cities and energy bases can decrease the agricultural water volume which is occupied by cites and energy bases to raise the guaranteed rate of agricultural water supply, and to provide water resources guarantee for the safety of food production in Yellow Rive Basin. Finally Effectively relieve the Yellow River water deficit: After the operation of the basin – to – basin water diversion projects, e. g., the West Line of South – to – North Water Diversion Project, Water Diversion from Hanshui River to Weihe River, etc., at the level of the year 2030, the water deficit outside river channel can be reduced by 6.78 billion m^3 under the annual mean condition, and the water deficit situation of the Yellow River can be greatly relieved.

3.2 Suppressing serious degeneration trend of eco – environment in the related areas

Heishanxia Section: Water supply to the areas adjacent to Heishanxia is increased by 0.78 billion m^3, the eco – environment state can be effectively improved through large areas of new type constructed oasis to relieve the pressure from local eco – environment bearing capacity greatly. Shiyanghe: 400 million m^3 water is supplied to Shiyanghe River to guarantee the water volume in downstream Minqin area, relieve the water deficit state, slow down the desertification progress, and promote the recover and improvement of the local eco – environment.

3.3 Recharging eco – environmental water inside channel, improving basic function of the Yellow River stem course

3.5 billion m^3 water is allocated inside channel, water and sediment regulation for the whole river is conducted through joint dispatch operation of the reservoirs on the stem to create harmonious water – sediment relationship in the Yellow River stem, raise the flood – discharging capacity of the main channel of the Yellow River stem, and reduce the channel deposition. Based on the preliminary analysis, under the condition of considering the upper – reach 3 – reservoir joint operation of Longyangxia, Liujiaxia and Heishanxia and considering the middle – reach 3 – reservoir joint operation of Guxian, Sanmenxia and Xiaolangdi, the channel deposition in Ningmeng Section, Xiaobeiganliu, and the downstream can be reduced by 92 million t in total and the sediment can be transporteal to the sea.

4 Conclusions

Since water resources in the Yellow River basin is poor and over – exploited, the water resource can not support the sustainable economic and social development in the basin and in the adjacent areas, leading to more and more prominent contradiction between supply and demand, water resources shortage, and worsening of eco – environment state. With the economic and social development in the basin, the contradiction between water resources supply and demand will be further accelerated, and it will be one of the main factors which will restrict the local sustainable economic and social development. The implementation of the West Line of South – to – North Water Diversion Project as soon as possible is the most effective approach to solve the water resources shortage and eco – environment worsening in the Yellow River basin. Under the condition of water diversion of 8 billion m^3 including 3.5 billion m^3 allocated inside and 4.5 billion m^3 allocated outside channel, the water demand from the important cities and energy bases in the Yellow River upper and middle reaches and in Hexi inland river areas at the level of the year 2030 can be basically satisfied, the eco – environment state of Heishanxia Eco – environmental Agriculture and Husbandry Base can be effectively improved, the channel deposition in Ningmeng Section, Xiaobeiganliu, and the downstream can be reduced by 92 million t in total and the sediment can be sent to the sea. The water deficit in the Yellow River basin can be greatly relieved, resulting in great economic, social and environmental benefit.

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Influence of Water Regulation on the Eco – environment in the Lower Reaches of the Heihe River

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Abstract: Water regulation has been carried out by the Heihe River Bureau since 2000, which aims at the existing eco – environmental problems in the lower reaches of the Heihe River. In order to objectively evaluate the influence of water regulation on the eco – environment, the changes of groundwater table, typical vegetation and East Juyan Lake have been analyzed in the lower reaches of the Heihe River, by means of field surveys and remote sensing. These results indicate that there exists obvious influence of water regulation on the eco – environment, and that the eco – environment is developing in a sustainable way in the lower reaches of the Heihe River.

Key words: influence, water regulation, eco – environment, the lower reaches of the Heihe River

The Heihe River is the second longest inland river in China, which is called "the Mother River" by the Hexi people. With the total area of 142,900 km^2, and the total length of 821 km, the Heihe River originates from the north of Qilian Mountain and flows through Qinhai Province, Gansu Province and Inner Mongolian Autonomous region (including 11 counties or banners). Its upper reach is from Yingluo Gorge upwards, the middle reach is between Yingluo Gorge and Zhengyi Gorge, and the lower reach is from Zhengyi Gorge downwards. The length of the lower reach is 333 km, and the area of the lower reaches is 80,400 km^2. The lower reach flows about 176km from Zhengyi Gorge to Langxin Mountain, then is divided into east river and west river downwards from the diversion gate in Langxin Mountain, then flows into East Juyan Lake and West Juyan Lake (Suoguonuoer and Gashunnuoer) respectively. Finally, the Ejina Delta oasis is formed by the East and West rivers in the interior of desert and Gobi, which has been an important ecological defense for the sandstorm in the northwest of China.

According to the historical recordation, there were abundant aquatic grasses in the lower reaches of the Heihe River. And the famous Ancient Juyan – Black City Oasis Culture was fostered in this region during 1,000 years from Han to Yuan Dynasties. The water area of East Juyan Lake and West Juyan Lake was 35 km^2 and 190 km^2 respectively during the period of 1928 ~ 1932 when the Chinese – Swedish Northwest Survey Team stayed there. In 1958 (wet year), the water area of those two lakes was 35.5 km^2 and 267 km^2 respectively. At that time, many species of grasses, such as populus euphratica, elaeagnus angstifolia, tamarix sp., haloxylon ammodendron, nitraria sibirica, glycyrrhiza uralensis, phragmites communis etc., were flourished on the two banks of the Ejina Delta and around the East Juyan Lakes, West Juyan Lakes and Gurinai Lake. In the past fifty years, the oasis were desertified seriously and the eco – environment were deteriorated suddenly, owing to water extraction in the upper and middle reaches, the increase of water supply for industry and agriculture and the unreasonable exploitation of land. For example, lakes became dry and the water quality became worse; the oasis decreased rapidly and the carrying capacity of pasture declined sharply and several rare animals disappeared; desert spreaded rapidly. The reasons for these eco – environmental problems are various, but the essential one is the water shortage in the lower reaches because lots of water is used for irrigation in the middle reaches since 1960s.

In order to prevent the eco – environment from deterioration and solve the outstanding problem, it was decided to implement the unified management and regulation in the Hei River. And the Heihe

River Bureau of Yellow River Conservancy Commission (YRCC), MWR was founded upon authorization in 1999. Since then, the water resources in this basin has been managed and regulated uniformly. Since the end of 1999, the unified water regulation began, and more water was regulated into the lower reaches of the Heihe River. After five years of water regulation, the spatial – temporal distribution of water resources has changed dramatically there. The outflow from the middle reaches has increased year after year. In terms of the relation of water diversion curve, it could be calculated that when the average inflow at Yingluo Gorge is 1.58 billion m^3, the average outflow at Zhengyi Gorge varied from the average discharge (0.73 billion m^3, no water regulation) during the period of 1997 ~ 1999 to 0.80 billion m^3 in 2000, 0.83 billion m^3 in 2001, 0.90 billion m^3 in 2002, or 0.95 billion m^3 in 2003 after water regulation. Especially, the runoff has reached to the capital of Ejina banner in 2001, to East Juyan Lake with the maximum water area of 23.5 km^2 in 2002 (where there's no water for 10 years), and to West Juyan Lake in 2003 (where there's no water for 40 years).

By means of the unified water regulation for several years, the temporal – spatial distribution of water resources has been varied greatly in the lower reaches of the Heihe River, which has brought positive effects on the eco – environment in the lower reaches. In this paper, by the field surveys and remote sensing data, the influence on the eco – environment is analyzed in the lower reaches of the Heihe River. And this analysis may provide some scientific proofs for the further water regulation and the further rehabilitation of the eco – environment in the lower reaches of the Heihe River.

1 Influence of water regulation on the groundwater level of the lower Heihe

1.1 Influence of water regulation on the groundwater level

The observation wells in the lower reaches of the Heihe River was founded in 1988. These wells are mainly distributed in the oasis along the east and west rivers and rarely on the edge of the oasis and desert. Especially, these wells are more concentrative near Langxin Mountain in the upper reaches of both East River and West River, Jirigelangtu in the lower reaches of East River and near Saihantaolai in the lower reaches of West River. Fig. 1 shows the varieties of groundwater level in several typical wells in the upper reaches of East River and West River, near the Jirigelangtu and Saihantaolai in the lower reaches of East river, as well as in the Ejina Oasis (1995 ~ 2004). It can be seen from Fig. 1 that the slow descending trend of groundwater level in the lower reaches of the Heihe River has been held back after water regulation for 5 years. Particularly, the groundwater level has been rising to some degrees in the lower reaches of the Heihe River since 2002. In 2004, the groundwater level increased to or near the historical maximum after 1995. Comparing the figure in 2004 with that in 2002, the groundwater level rose by 0.22 m both in East River and West River, by 0.79 m in Jirigelangtu, by 0.5 m in Saihantaolai, and by 0.42 m in the whole Ejina Oasis.

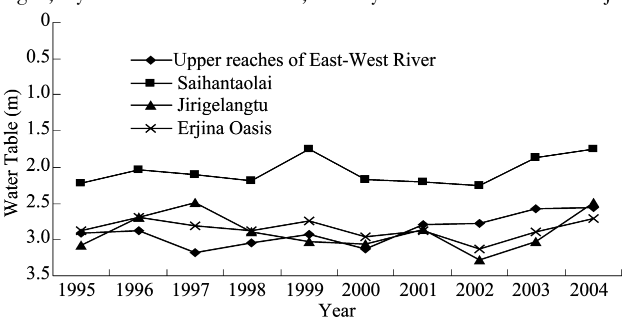

Fig. 1 Inter – annual varieties of groundwater level in main regions of the lower reaches of the Heihe River

1.2 Relation between groundwater level and vegetation

Lots of surveys indicate that there is a remarkable correlation between the evolvement of natural vegetation and groundwater level (Table 1) owing to the rare rainfall, and that groundwater level to maintain the normal growth of natural vegetation is various according to different vegetation. Therefore, it is necessary to meet the groundwater supply for the maintenance of the normal growth of natural vegetation. Natural vegetation in the lower reaches of Heihe River could be protected and rehabilitated effectively, if the demand of normal growth of natural vegetation is met by scientific water regulation.

Table 1 Relation between water level and the growth of plants in Ejina banner

Vegetation community	Water table and growth condition			
Populus euphratica	<4 m normal growth	4 ~ 6 m, hidebound, bald, the leaves fade even few plants die	6 ~ 10 m, most of the plants blast	>10 m, all the plants die
Elaeagnus angstifolia	2 ~ 3 m normal growth	4 ~ 5 m, hidebound, blasted, even few plants die	5 ~ 6 m, most of the plants blast and degraded	>6 m; most of the plants die
Tamarix sp. Nitraria sibirica	<5 m normal growth	5 ~ 7 m, degradation, blasted, even few plants die	7 ~ 8 m degraded seriously, most of the plants die	>8 ~ 10 m, all the plants die

2 Influence of water regulation on typical plants

2.1 Influence of populus euphratica to water regulation

According to the survey, after water regulation for 5 years in the Heihe River, the transverse influence of water regulation on populus euphratica has reached to the region, where is 800 m away from the watercourse. And the influence of water regulation on populus euphratica in different periods changes along with distances. During the 2nd year of water regulation (In 2001), the indexes of populus euphratica within the region (100 m away from the watercourse), such as the average height and the thorax diameter etc., increased obviously; during the 3rd year (In 2002), the indexes of populus euphratica within the region (100 ~ 200 m away from the watercourse) reached to the peak; during the 4th year (In 2003), populus euphratica within the region (200 ~ 300 m away from the watercourse) grew rapidly. Table 2 ~ Table 6 show the growth of populus euphratica before or after water regulation at different sites of East – West River in terms of the field survey in Aug. 2005. The degree of growth is an important quantitative index to evaluate the recovery of populus euphratica. According to the survey results, the year of 2000 is the inflexion for the influence of populus euphratica's growth. And the nearer populus euphratica is to the watercourse, the more rapid its growth is. Obviously, there is a correlation between the growth degree and the water level. However, the influence of the water regulation on populus euphratic is inconspicuous, in the region which is more than 1,000 m away from the watercourse.

Table 2 Survey results of the growth indexes for Populus euphratica at the cross section near Weitong Bridge in Dongfengchang before and after water regulation

Distance to the watercourse (m)	Age of populus euphratica (year)	Growth degree for 5 years before water regulation (mm)	Growth degree for 5 years after water regulation (mm)	Concomitant vegetation
100	11	14.2	16.1	Phragmites communis Tamarix sp. Achnatherum splendens Sophora alopecuroides
260	8	—	2000 2.5 2001 3.2 2002 3.1 2003 3.5 2004 3.2	Tamarix sp. Achnatherum splendens Sophora alopecuroides
500	16	12.3	13.2	Tamarix sp. Sophora alopecuroides
1,000	13	10.8	10.9	Tamarix sp.

Table 3 Survey results of the growth indexes for Populus euphratica at the left cross section of Yidao River near Daxi'aobao before and after water regulation

Distance to the watercourse (m)	Age of populus euphratica (year)	Growth degree of the thorax diameter for 5 years before water regulation (mm)	Growth degree of the thorax diameter for 5 years after water regulation (mm)	Water level before water regulation (m)	Water level after water regulation (m)
0	85	11.5	15.0	2.27	1.32
100	26	10.5	14.2	2.64	1.87
200	24	7.5	10.0	3.18	2.55
300	12	8.3	9.5	3.52	3.05
500	22	9.8	10.2	4.11	3.98
1,000	35	7.4	7.5	4.67	4.55

Table 4 Survey results of the growth indexes for Populus euphratica at the right cross section in the middle reaches of the Liudao River before and after water regulation

Distance to the watercourse (m)	Age of populus euphratica (year)	Growth degree of the thorax diameter for 5 years before water regulation (mm)	Growth degree of the thorax diameter for 5 years after water regulation (mm)	Water level before water regulation (m)	Water level after water regulation (m)
0	14	9.6	12.3	2.83	1.54
100	31	8.2	10.5	3.14	2.01
200	18	10.4	11.3	3.31	2.89
300	20	9.3	9.8	3.85	3.64
500	62	7.9	8.1	4.53	4.32
1,000	84	6.5	6.5	5.36	5.28

Table 5　Survey results of the growth indexes for Populus euphratica near the right cross section near the Ebeichagan in the upper reaches of the East River both before and after water regulation

Distance to the watercourse (m)	Age of populus euphratica (year)	Growth degree of the thorax diameter for 5 years before water regulation (mm)	Growth degree of the thorax diameter for 5 years after water regulation (mm)	Water level before water regulation (m)	Water level after water regulation (m)
0	15	14.3	16.1	1.32	1.28
100	13	12.5	13.4	1.98	1.88
200	21	13.7	14.3	2.54	2.46
500	30	8.5	9.0	3.15	3.12
1,000	52	7.8	7.9	3.63	3.58
1,500	62	7.2	7.2	4.69	4.64

Table 6　Survey results of the growth indexes for Populus euphratica at the left cross section near the Saihantaolai in the West River both before and after water regulation

Distance to the watercourse (m)	Age of populus euphratica (year)	Growth degree of the thorax diameter for 5 years before water regulation (mm)	Growth degree of the thorax diameter for 5 years after water regulation (mm)	Water level before water regulation (m)	Water level after water regulation (m)
0	20	13.2	16.9	2.15	1.28
100	25	11.8	13.9	2.88	1.88
200	19	9.7	11.6	3.52	2.46
500	32	10.5	11.8	4.05	3.12
1,000	24	8.5	8.8	4.38	4.02
1,500	58	6.2	6.3	4.99	4.64

2.2　Influence of water regulation on tamarix sp

According to the field survey, the transverse influence of water regulation on tamarix sp is also evident in that past 5 years. And this influence changes along with the distance between the tamarix sp. and the riverway. Table 7 and Table 8 show the growth indexes of tamarix sp at the cross sections of East River and Yidao River before and after water regulation.

As shown in these two tables, when compared with that before water regulation, the growth degree of thorax diameter of tamarix sp. at the section of East River is a little larger than that at the section of Yidao River. And at the same cross section, the difference of the growth degree of thorax diameter is quite little when the distance away from the watercourse is longer.

Table 7 Survey results of the growth indexes for Tamarix sp. at the cross section of East River before and after water regulation

Distance to the watercourse (m)	Age of Tamarix sp. (year)	Growth degree of the subaerial diameter for 5 years before water regulation (mm)	Growth degree of the subaerial diameter for 5 years after water regulation (mm)	Coverage (%)	Concomitatn vegetation
100	10	11.3	11.5	70	*Sophora alopecuroides*
200	17	10.8	12.1	50	—
300	11	10.5	11.9	47	—
400	12	10.8	11.7	50	
500	11	11.0	11.7	40	*Sophora alopecuroides*
600	14	10.1	10.6	43	*Sophora alopecuroides*
1,000	10	10.2	10.3	35	—

Table 8 Survey results of the growth indexes for Tamarix sp. at the cross section of Yidao River before and after water regulation

Distance to the watercourse (m)	Age of Tamarix sp. (year)	Growth degree of the subaerial diameter for 5 years before water regulation (mm)	Growth degree of the subaerial diameter for 5 years after water regulation (mm)	Concomitant vegetation
0	10	11.3	12.5	*Populus euphratica*
100	14	8.9	10.0	*Populus euphratica* *Kareliniacaspia (Pall.) Less.*
200	12	8.6	9.5	*Populus euphratica*
300	12	8.9	9.5	*Kareliniacaspia (Pall.) Less.* *Sophora alopecuroides*
500	15	9.6	10.0	*Populus euphratica*
1,000	19	7.9	8.1	*Populus euphratica*

3 Influence of water regulation on the vegetation near East Juyan Lake

The vegetation had been seriously degraded in or around East Juyan Lake since it became dry in 1992. And there were a few of innutrient Phragmites communities in the lake and lots of died tamarix sp. around the lake before water regulation in July 2002. After the flow entered East Juyan Lake in the 1st water regulation in 17th, July 2002, the water had been regulated for 6 times in the following 3 years, and even the maximal water area was near 40 km^2. The East Juyan Lake was the most influenced region by water regulation. According to the field survey, the vegetation in the lower reaches has changed evidently, when compared in the end of water regulation with that before water regulation. All the survey results are shown in Table 9 and Table 10.

Table 9 Survey results of the vegetation in and around East Juyan Lake before water regulation

Sepcimen position	Dominant vegetation	Coverage (%)	Concomitant vegetation	Other features
In the lake (dry)	*Phragmites Communis*	1	—	The average height is 6 cm
Around the lake	*Tamaris sp.*	13	*Nitraria sibirica*	65% bald die

Table 10 Survey results of the vegetation around East Juyan Lake after water regulation

Specimen position		Dominant vegetation	Coverage(%)	concomitant vegetation	The average height(cm)
Southwestern bank	Within 100 m to lake bank	Kalidium foliatum(Pall.)Moq. Tamarix sp.	10		11
	100 m away form lake bank	Tamarix sp.	8	Suaeda heteroptera Kitag	
Southern bank	Within 60 m to lake bank	Kalidium foliatum(Pall.)Moq. Tamarix sp. Phragmites communis	37	Kareliniacaspia(Pall.)Less. Suaeda heteroptera Kitag and so on	
	Within 60 ~ 120 m to lake bank	Tamarix sp. Kalidium foliatum(Pall.)Moq.	8	Phragmites communis Nitraria sibirica Suaeda heteroptera Kitag	13
	120 m away from lake bank	Tamarix sp.	18	Nitraria sibirica	28
30 m from bank to center in the lake		Phragmites communits		—	54
Southeastern bank	Within 60 m to the lake edge	Kalidium foliatum(Pall.)Moq. Suaeda heteroptera Kitag	17	Tamarix sp. Nitraria sibirica Kareliniacaspia(Pall.)Less.	
	60 m away from lake bank	Tamarix sp.	35	Alhagi sparsifolia Nitraria sibirica Suaeda heteroptera Kitag	17
Within 100 m to botyh sides of the water inlet		Tamarix sp.	56	Suaeda heteroptera Kitag	86

It can be concluded from Table 9 and Table 10 that before water regulation, the coverage of vegetation was low, the varieties were few, and most of the vegetation were innutrient in or around East Juyan Lake. However, after water was regulated during three successive years, the coverage and the varieties of vegetation increased evidently, and all the vegetation grew well. The reasons are that after water flowing into East Juyan Lake, both the lateral and vertical infiltration caused the increase of soil water content and groundwater level around the lake. Accordingly, water demand for the normal growth of vegetation was met, and the vegetation appears to grow towards the good succession.

4 Remote sensing analysis for the influence of water regulation on the ecosystem

As an important measure, satellite remote sensing analysis plays an important role in monitoring the changes of geo - environment. In order to further analyze the influence of water regulation on the eco - environment of the oasis in the lower reaches of the Heihe basin, remote sensing is applied to analyze the area and coverage of pasture, populus euphratica, shrub with different coverage of vegetation in different areas of the lower reaches, as well of the area changes of Gobi, desertation area, saline - alkali land etc. before and after water regulation.

According to the statistic analysis of remote sensing, it is found that there are great changes on the area and coverage of both the pasture and the shrub, as well as the area of Gobi, desertation area, saline - alkali land, when comparing the statistic data in 1998 with that in 2004 (Table 11). Then the conclusions can be drawn as follows: ① After water regulation and improvement of the Dingxin Irrigation District, the growth of forest and pasture there became worse, because of the decrease of water supply from the Heihe River and the canal lining. At the same time, the area of saline - alkali land reduced due to the decrease of groundwater level. ② The growth of forest and pasture in Dongfengchang changed a little except for those along the river, because there was no more water supply and no improvement in Dongfengchang after water regulation. ③ The eco – environment in East – West River had been greatly improved since water regulation and treatment in the Heihe River. For example, the areas of Populus euphratica, pasture and shrub increased; the growth of vegetation was improved; and the areas of Gobi and desertation area decreased when compared with those before water regulation. The oasis in East – West River is the core region in the lower reaches of the Heihe River. Improvement of the eco – environment in the oasis indicates that the continuous deterioration of the eco – environment in the lower reaches has been controlled effectively. ④ The benefits of the two lakes are the most obvious, especially around the East Juyan Lake. Not only the water area always remains larger during the whole year of 2004, but also the eco – environment around this region had been improved greatly. For instance, the Phragmites communis and the Achnatherum splendens, etc., which had dried for years, became more flourishing. In a word, the oasis in the lower reaches of the HeiheRiver, where the pasture, Populus euphratica and shrub grow, increased by 40.16 km^2. In which, there was 8.16 km^2 of pasture, 4.84 km^2 of Populus euphratica and 25.33 km^2 of shrub. All these may show that the area of desertification was decreasing, while the area of oasis was increasing after water regulation. The trend of shrinking of the oasis in the lower reaches has been held back after water regulation and the farthering.

Table 11 Increment Statistics of the remote sensing data in the lower reaches of the Heihe River between 1998 and 2004

Units: km^2

Item	Dingxin area	Dongfengchang area	East – West River area	two lakes area
pasture area with larger coverage	1.75	0.19	2.15	1.19
pasture area with middle coverage	6.45	0.04	2.96	7.15
pasture area with smaller coverage	3.34	–0.1	1.71	7.29
shrub area with larger coverage	—	1.7	22.07	5.9
shrub area with middle coverage	—	–1.45	–6.05	–0.39
shrub area with smaller coverage	0.01	–0.1	–11.6	–0.82
Populus euphratica area with larger coverage	—	0.05	6.35	—
Populus euphratica area With middle coverage	—	–0.06	–0.82	—
Populus euphratica area with smaller coverage	—	–0.1	0.89	—
other forest area	0.8	0	0.05	—
Gobi area	–0.42	–0.03	–10.77	–9.99
Desertation area	–5.53	–0.03	–1.67	–12.92
Aline – alkali land	–1.03	0	—	—

5 Conclusions

Based on the above, the conclusion is summarized as follows:

(1) The trend of continuous decrease of groundwater level has been held back in Ejina banner after water regulation in the lower reaches of the Heihe River. Even the groundwater level went up again in some sites. Especially, the groundwater level in the lower reaches of the Heihe River has risen to different degrees since 2002. In 2004, the groundwater level is near or up to the historical maximum since 1995. Comparing the figure in 2004 with that in 2002, groundwater level has risen by 0.22 m both in East River and West River, by 0.79 m in Jirigelangtu, by 0.5 m in Saihantaolai, and by 0.42 m in the whole Ejina Oasis.

(2) The influence of water regulation on populus euphratica and Tamarix sp was obvious. And

the velocity of growth became higher. According to the survey for the growth of populus euphratica and Tamarix sp within the influence region before and after water regulation, it is found that the velocities of growth of both populus euphratica and Tamarix sp became higher obviously than those before water regulation. Moreover, the nearer the distance is to the watercourse, the better the growth were.

(3) The trend of shrinking in the Ejina Oasis in the lower reaches of the Heihe River has been held back. And the biodiversity has increased as well. The area of populus euphratica around East – West River, or in the lower reaches of Heihe River increased from 366 km^2 before water regulation to 375 km^2 after water regulation. The area of the pasture and the shrub increased by 6.8 km^2 and 5 km^2 repectively, while the area of Gobi and sand area decreased by 1.67 km^2 and 10.77 km^2 respectively. Especially, the eco – environment has changed most obviouslly in East Juyan Lake. Not only the water area of the lake always kept larger during the overall year of 2004, but also the eco – environment around the lake was improved dramatically. During the period of 1998 ~ 2004, the area of pasture and shrub increased by 15.6 km^2 and 14.5 km^2 respectively, and the area of Gobi and sand area decreased by 9.99 km^2 and 12.92 km^2 respectively. The biodiversity has been increasing in Juyan Lake because many wild animals rehabitated.

(4) Some achievements have been obtained since water regulation in the lower reaches of the Heihe River. The trend of continuous deterioration of the eco – environment has been primarily held back in the Ejina Oasis, but it is still a long – term tough task to improve and rehabilitate the eco – environment in the Ejina Oasis. In order to held back the continuous trend of deterioration of the eco – environment in this region, rehabilitate the important eco – environment barrier, and realize the majestic landscape in Juyan Lake, it is necessary to improve the comprehensive management in the lower reaches of the Heihe River, on the basis of the further perfection of the existing achievements.

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Introduction to the International Water Transfer Projects and Comparison with the East Route of Chinese South to North Water Transfer Project

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Abstract: Addressing water scarcity or water quality in one or more regions by transporting additional supplies from hydrological richer basins has been long – time practiced and is known as Inter Basin Water Transfer (IBWT). IBWT projects have been planned and constructed worldwide, at different scales and for different reasons and the history of large water structure construction is filled by the alternate successes and failures of such human endeavors. Failures, indeed, are measured not only against the structural performances of the IBWT project but also, and most often, against the capability of the infrastructure to partially or completely fulfill the requirements for which it was originally designed. The possibility of predicting some of these failures is never an easy and straightforward task and complexity increases with the size of the project. Comparing a proposed or undergoing project to other of similar size and/or similar characteristics could greatly help to avoid common mistakes and provide guidance in dealing with the construction and management of the structure.
Key words: Inter – Basin Water Transfer (IBWT)

1 Inter basin water transfer (IBWT) projects

The IBWT projects are fundamentally the technical answer to the need for water resources wherever they are scarce. They had been discussed considering the social, ethic, economical and legal technical aspects, in this order of importance.

Despite many experiences on long distance water transfer are reviewed critically from the past and the present, many other focal issues emerge.

Mass transfer of water is often justified by considering only the direct cost of transporting water. Seldom are the values of services foregone by the exporting region due to reduction of their water availability. Various other feasible alternatives to inter – basin water transfer are often not investigated. There is a tendency within the engineering and economic professions to opt for technological solutions, while "soft" options tend to be neglected (Biswas, 1979). Since water resources development is dominated by these two professions, there is a tendency to opt for technological fixes before all viable alternatives are explored, such as more efficient use of available water, re – use of waste water, better management of watersheds, improved integration of surface and groundwater supplies and changing cropping patterns.

Often the agricultural sector is the major beneficiary of water transfer projects. Thus, much of the analysis concentrates on agricultural benefits, and social objectives like income redistribution, alteration in regional growth rates and patterns, reduction in unemployment and environmental protection are not considered. To a certain extent this can be explained by the difficulties encountered in quantifying social and environmental benefits and costs.

The legal implications of interstate and international water transfers are quite complicated. Adequate legal and institutional frameworks for such developments are rare, and currently there is no process for speedy resolution of these conflicts. This point can be quickly realized by the present disputes that exist between states and between nations on the use of interstate and international rivers and lakes (Biswas, 1983).

Therefore there are a number of problems associated with large – scale transfer of water from one region to another; the magnitude of the problems will differ from one project to another, but some of the major variables that should be considered are the following.

(1) Physical System. (a) Water Quantity: level; discharge; velocity; groundwater; losses. (b) Water Quality: sediments; nutrients; turbidity; salinity and alkalinity; temperature effects; toxic chemicals. (c) Land Implications: erosion; sedimentation; salinity; alkalinity; waterlogging; changes in land use patterns; changes in mineral and nutrient contents of soil; earthquake inducement; other hydrogeological factors. (d) Atmosphere: temperature; evapotranspiration; changes in microclimate; changes in macroclimate.

(2) Biological System. (a) Aquatic: benthos; zooplankton; phytoplankton; fish and aquatic vertebrates; plants; disease vectors. (b) Land – based: animals; vegetation; loss of habitat; enhancement of habitat.

(3) Human System. (a) Production: agriculture; aquaculture; hydropower; transportation (navigation); manufacturing; recreation; mining. (b) Socio – cultural: social costs, including resettlement of people; infrastructural developments; anthropological effects; political implications.

2 IBWT projects evaluation

One of the objectives of this paper is to compare some key international experiences in Inter Basin Water Transfer projects and to provide a framework background to compare the Chinese Water Transfer Project's performance in its East Route to other similar experiences worldwide.

Firstly the most relevant projects to be considered will be selected. Secondly, a methodology will be prepared to assess the performance of each different project analyzed. The criteria for project evaluation will consider how each project performs against a defined set of evaluation criteria.

The evaluation criterion of the IBWT projects was developed by the Professor W. E. Cox. Criteria have to be considered as recommendations rather than absolute rules, but that can be used as evaluation instruments of an IBWT project and/or a comparison between some projects of water diversion.

The arguments considered by W. E. Cox are the following:

(1) Technical and Economic Feasibility. Besides technical and economic feasibility, the projects need to be evaluated in a comprehensive evaluation framework, that accounts for related aspects such as environmental, legal, ethical issues. The costs for providing water services need to be recovered.

(2) Environmental Impact Assessment. Environmental considerations should be an organic part, and not just an addendum to the projects. Some of the limitations of project – by – project Environmental Assessment (EA) may be overcome by strategic EA (that looks at a range of possible interventions over a long period, to reach certain objectives).

(3) Ethical Concepts. Ethical arguments in favor of water transfers have different facets: to receive water when it is deficient is a basic human right and to provide water is an act of solidarity, a sign of good will between neighbors, sometimes even a token of charity.

(4) The Legal Context. Laws (or plan, treaties, etc.) regulating IBWT became necessary as the scale of proposed projects increased, in particular to provide an opportunity for elected officials (parliament) to discuss the advantages and disadvantages of the proposed project and make a decision in all openness. The legal aspect of inter – basin water transfer is affected by the legal status of the river basin.

(5) Social Aspects, Information and Communication. In modern times, social requirements oblige the promoters of IBWT project to launch a comprehensive, transparent and participative decision – making process. Participation and public information in all stages of planning IBWT is essential.

(6) Institutional models. The institutional complexity of inter – basin transfers increases with the number of political and administrative jurisdictions involved. Whereas large transfers within one

country or state may be relatively trouble – free because the main responsible government agency governs both the donor and the recipient region, international solutions promoted by regional and international organizations (such as European Commission), can be complex from an administrative perspective and must be devised and adapted to the reality of the respective basins.

(7) Decision support. IBWT projects may be efficiently supported by modelling tools for multi – criteria decision making, of different kinds; an essential feature of these is the possibility to assess uncertainty and estimate the value of social and economic criteria. Professional analyses should support the decision making process and provide unbiased information to the decision makers and the general public.

On the basis of these arguments Professor Cox defined as evaluation criteria for justifying or rejecting IBWT projects:

Economic productivity impacts. Criterion 1: The IBWT receiving region must face a water shortage determining a decreasing productivity and human welfare worsening, that can't be prevented reducing the water demand and developing alternative water supplies. Criterion 2: The water resources of the supplying region must suffice to satisfy the transfer demand without affecting the future development of the region.

Environmental quality impacts. Criterion 3: The project needs a comprehensive environmental impact assessment that must indicate with a reasonable degree of certainty that it will not substantially degrade the environmental quality both in the origin area and the delivery area; however, transfer may be justified where compensation to offset environmental damage is provided.

Social – cultural impacts. Criterion 4: The project needs a comprehensive socio – cultural impacts assessment that must indicate with a reasonable degree of certainty that it will not cause substantial socio – cultural disruption both in the origin area and the delivery area; however, transfer may be justified where compensation to offset potential socio – cultural is provided.

Benefit distribution considerations. Criterion 5: The benefits of the project must be equally divided between the supplying and receiving region.

The major principles of IBWT projects are an integrated water management and the respect of the environment.

3 Identification of the main water diversion project

The search for IBWT case studies was undertaken through the web, together with international experts; One of the major problems related to the lack of information about the IBWT project is due to the fact that some have not started or are in a preliminary phase. someone the other hand, in old projects information is not completely available.

Every project is evaluated against the project evaluation criteria, and the results are presented in a "Lessons Learnt Matrix" (LLM). It consists of a matrix that resumes the experiences acquired in the execution of programs and projects which can provide value – added direction to the formulation and execution of future development and operational initiatives. Each case study has been separately assessed in order to identify the adequacy or the lack of information about various aspects of the IBWT project useful for the development of a lessons learnt matrix (LLM).

In the following section a brief description of the case study selected from the IBWT international projects scenery is reported. Due to the limitation of the space, not all the eleven cases assessed by the LLM will be described hereafter. The aim of this description is not to give a technical – engineering description of each project, but to provide an overview of the criteria used for evaluating the project's accountability for the full context that surrounds IBWT projects.

3.1 Lesotho – Republic of South Africa project (South Africa case study)

Description of the project. The project diverts water from the highlands of Lesotho (from the Senqu/Orange river) to the Vaal River catchment in the water – short Gauteng province. It includes 7 dams and 120 km of canals. The project aimed at transferring up to 5,677 m^3/a (82 m^3/s).

Phase 1 was completed in 2003. Cost of the project: 4.40×10^9. Basic situation of the water shortage: water shortage in Gauteng province. Benefits of the project: For South – Africa: ①hydropower for uses in sub – region. ②Economic and domestic water supply. For Lesotho: ①New (or expansion of) infrastructure (roads, communication and electricity system). ②Health facilities, job opportunities. ③Improvement of water supply and sanitation of communities. Socio – economic impacts: Positive impacts: ①Improvement of water supply for irrigation. ②New water supply for RSA. ③New infrastructures (see benefits). Negative impacts: ①loss of arable land, grazing land and dwellings for the construction work. Environmental impacts. Positive impacts: No positive impacts. Negative impacts: ①Reduction of fish population. ②Thermal stratification in reservoirs during summer that can seriously affect downstream fish breeding, habitat and production. ③Extreme pressure on wildlife and flora. Mitigation and compensations. Mitigation of downstream impacts through adjustment of flow releases. Compensation programmes that aimed to repay communities for the losses (virtually all lost community assets such as communal land resources have been replaced by other resources, not cash).

3.2 Aqueduct from Rhone to Catalonia region (French – Spanish case study)

Description of the project. The project diverts water from the Rh? ne River to the Catalonia region in Spain through an aqueduct of 320 km length completely underground from Montpelier to Cardedeu. The construction of 2 pumping station is expected. The project aims at transferring up to 300×10^6 m^3/a (10 m^3/s). The project is in a preliminary phase and it is expected to be completed in 2025. Cost of the project: 903×10^6. Basic situation of the water shortage: ①water shortage in Catalonia region during summer. ②Serious urban water deficit. Benefits of the project: ①water supply for Catalonia region. ②Reduction of the over – exploitation of Ter and Llobregat River. ③Relieve the Ebre River from the numerous water takings. ④Long – term development (protection of water resources, of flora and fauna). ⑤Integration of the southern Europe. Socio – economic impacts. Positive impacts: solve drinking deficit in Catalonia region. Negative impacts: social – economic dispute of French farmers that fear for Spanish competition with Spanish agricultural production (but the diverted water is intended only for drinking uses and not for agricultural uses). Environmental impacts. Positive impacts: ①No expected impacts on Rhone River (also considering climate change). ②Reduction of the over – exploitation of Ter and Llobregat River and improvement of their water quality. ③Relieve the Ebre River from numerous water takings. ④Preservation of coastlines from degradation due to desalinisation establishment. ⑤ Protection of underground resources. Negative impacts: Excavation of rock. Mitigation and compensations: The diverted water quality will be ensured through a monitoring and management plan. The management plan must also to reassure French farmers, in direct competition with the Spanish producers, that the diverted water are intended only for drinking uses and not for agricultural use (Fig. 1).

3.3 Water diversion projects in California (Central Basin Project – CVP)

Description of the project. The project diverts water from the Sacramento – San Joaquin River delta to southern CA. It includes 18 federal reservoirs, 4 reservoirs jointly owned with the State Water Project, 11 power plants, 3 fish hatcheries, and 1,300 km of canals. The project aimed at transferring water up to 86.3×10^8 m^3. The project began construction in the 1940s. Cost of the project: No information about cost. Basic situation of the water shortage: ①Drought in the southern regions. ②Pressure on depleted groundwater aquifers (that caused land subsidence, massive damage to urban and rural infrastructures). Benefits of the project: ①Water for farmland irrigation and supply for 2 million urban customers. ②River regulation and flood control; navigation, power generation, recreation. ③Improvement of the welfare of the state's farming communities and support the growth of cities and industries. ④Mitigation of exploitation of groundwater aquifers and decrease land subsidence. Socio – economic impacts. Positive impacts: solve social and economic

Fig. 1　Rhone to Catalonia Project

development (industrial, agricultural). Negative impacts: in the north: sea water intrusion and high salinity in water supplies for formers urban communities. Environmental impacts. Positive impacts: ①Decrease groundwater exploitation. ②Decrease of land subsidence. Negative impacts: ①Massive ecological changes. ② In the north: sea water intrusion and high salinity in water supplies for wildlife; loss of wetlands converted in farms and bird and waterfowl migration; acceleration of leeching of selenium into ponds (death and deformation). ③ in the south: the diversion from Mono Lake tributaries (Los Angeles) in the Owens Basin caused lake level's drop and salinity increase (threatening shrimp and bird, and uncovering lake bed stretches that contain high levels of alkali [damage to respiratory system and public health hazard]). Mitigation and compensations: 1978; Water Right Decision. 1485; that established flow and water quality standards to protect: ① municipal and industrial water supply, ② agriculture, and ③fish and wildlife. 1987; comprehensive ecosystems plan for protecting the ailing Sacramento – San Joaquin river estuary. 1992; the Central Basin Project Improvement Act changed CVP operation and allocation for fish and wildlife protection and restoration. 1980s ~ 1990s; water rights for reduction of water diversion in the Owen Basin to restore Mono Lake(Fig. 2).

3.4　Iraq – Desiccation of the Mesopotamian marshlands – Diversion from the Tigris and the Euphrates

Description of the project. The project designed by the previous Iraqi regime aimed at diverting the water flows from the Tigris and the Euphrates away from the marshlands by the sea. The project aimed to support agricultural developments. In 2003 the Iraqi ministry of water resources started the rehabilitation of the Iraqi marshlands in collaboration with the Italian Ministry of the Environment and Territory. Cost of project: unknown. Scope of the project. For the Tigris river: Creation of a diversion canal (the Prosperity River) to divert the flows of the Tigris sub – tributaries from entering the central marsh. For the Euphrates: Closing of the original channel downstream Nassiriyah. Creation of a channel to divert flows of the Euphrates directly to the sea(Fig. 3,Table 1).

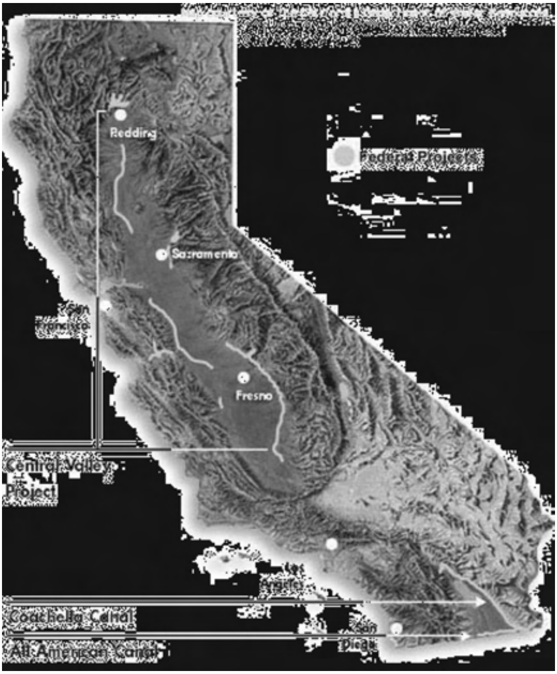


Fig. 2 Scheme of the Central Basin Project

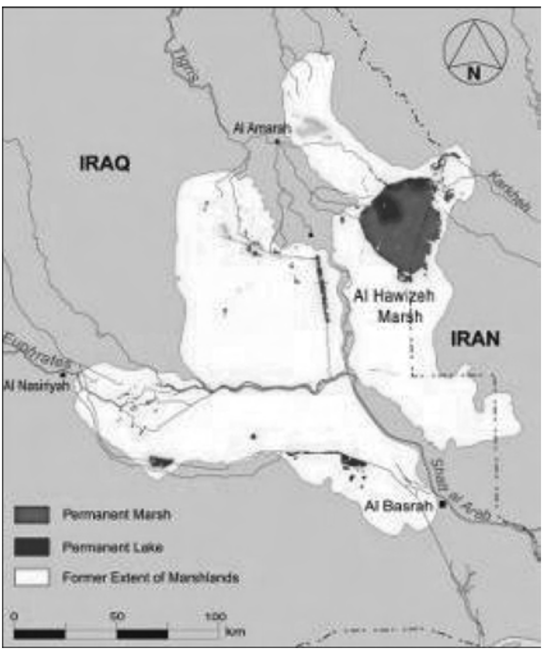


Fig. 3 The marshlands desiccation

Table 1

River system	Dry year(BCM)	Average year(BCM)	Wet year(BCM)
Tigris	19	49	97
Euphrates	9	28	63

Socio – economic impacts. Positive impacts: ① Agricultural development. ② Oil fields protection. Negative impacts. ①Dismiss of the marsh dwellers' way of life. ②200,000 inhabitant refugees. ③ Destruction of the local economy linked to fishing and reeds handcrafting. Environmental impacts. Positive impacts: None. Negative impacts: ①Destruction of the marshlands environment. ②Ecological disaster (transformation of wetlands in desert). ③Modification of the climate. Mitigation and compensations: Originally the Saddam's regime did not prepare any mitigation or compensation. The desiccation of the marshlands was managed in a very repressive way. Rehabilitation Program: After the fall of Saddam's regime in 2003, the New Eden project aimed at the rehabilitation of the Iraqi marshlands was launched. This program sponsored by the Italian Ministry of Environment is dedicated to support the Iraqi authorities in the sustainable management of the water resources for the rehabilitation of the former wetlands. The program is to be completed in collaboration with various international organisations. Modelling activities are developed for a comprehensive understanding of every technical, social, hydrological and environmental component of the program.

3.5 Nile – North Sinai Agricultural Development Project (North Africa – Middle East case study)

Description of the project. The system diverts water from the Nile River to the north Sinai region. The project is divided in five blocks over three administrative regions: the Port Said Governorate (10%), the Ismailiya Governorate (20%) and the North Sinai Governorate (70%). Part of the project was completed in the 1987. Cost of the project: The cost is about 1.5 billion dallar. Basic situation of the water shortage: ①water deficiencies in the Sinai desert due to climate change and population increase. ②Groundwater limited in quantities and often saline. ③Limitation to population and economic growth. Benefits of the project: ①increasing agricultural production through agricultural and stock development; improving income distribution. ② Generating employment through the settlement of smallholders and graduates from among the rural population of the over – populated areas of Egypt. Socio – economic impacts. Positive impacts: ①agricultural production, the establishment of settlement infrastructure (more educational facilities, health services, power supply, communication services, and roads). Negative impacts: ①the water entering can increase the incidence of infectious diseases and exposure of settlers and the indigenous population to allergenic and carcinogenic contaminants. ②Water shortage will result in salinization problems, reduced agricultural production and, eventually, farm income. Environmental impacts. Positive impacts: ①attraction of numerous bird species on migration. ②reduction in sand dune encroachment and stabilization of moving sand dunes. Negative impacts: ① loss of important habitats for flora and fauna communities and archeological sites. ②groundwater flow of contaminated water (containing pesticides and enriched with nutrients) and salinization. Mitigation and compensations: A total of 26 remedial and mitigatory measures have been proposed: 4 for project location, 11 for design, 1 for construction, and 10 for operation(Fig. 4).

Fig. 4 Scheme of the five block of the North Sinai Agricultural Development project

4 The Lessons Learnt Matrix (LLM)

In the LLM each project was assigned one column where the "score" to evaluate its performance against various criteria was reported These criteria have origin in the evaluation criteria of professor W. E. Cox previously mentioned. The choice of the LLM criteria started from the considering that all selected projects were consistent with Criterion 1, i. e. water transfer to the receiving water is the only way to relieve its shortage.

The evaluation of each project allowed the identification of best practice for development and management of such kind of projects. Comparisons with the South – North Water Diversion Project were made in order to identify which lessons can be learnt from other IBWT projects and adapt them to the South – North water diversion project. The Chinese contribution also provided valuable experience for upgrading the international knowledge on IBWT.

The lesson learnt matrix was set up for all the eleven international case studies chosen (not all of them have been described above). The lack of homogeneity of certain information on several projects did not permit to compare in detail every project. Every project was however illustrated within the LLM: I) Lesotho Republic of South Africa water transfer project (South African case study); II) Aqueduct from Rhone to Catalonia region in Spain (French – Spanish project); III) Texas Water Plan (North American project); IV) California Water transfer projects; V) Iraq marshlands desiccation program; VI) SIBARAL (Central Asian project); VII) Brazil, Sao Fransisco River Inter – Basin Transfer Project; VIII) Israel National water Carrier (Middle East case study); IX) Jordan east Ghor canal (Middle East case study); X) Nile – North Sinai (North African case study); was based on the evaluation criteria previously described, mostly focusing on the projects impacts and on their mitigation and compensation effects, the consideration of a monitoring plan, and the decisional model for the diverted water management.

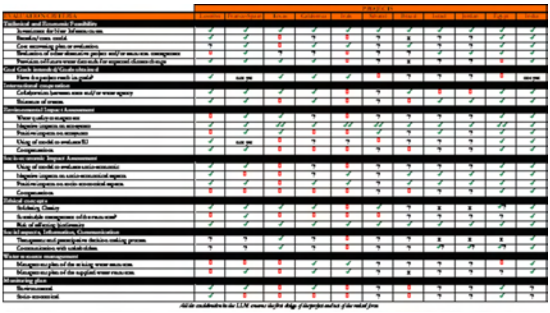
At the same time the LLM assessed whether projects were economically feasible, if there is international cooperation between intrastate and interstate water agencies. The LLM also considered whether a project had been chosen among alternative solutions, such as use or a better management of local resources (Table 2).

Table 2 The LLM Matrix

	PROJECTS			
EVALUATION CRITERIA	1	2	…	n
Technical and Economic Feasibility				
Investment for New Infrastructure				
Benefits of the project				
Cost Recovering				
Major Technical challenges				
Environmental Impact Assessment				
Water quality management				
Positive and Negative impacts on ecosystem				
Compensations				
Ethical concepts				
Solidarity, Charity				
Sustainable management of the resources				
Risks of affecting biodiversity				
Transparency of the decisions				
Legal Context				
Existence of a Legal instrument				
Situation of the project / International laws				
Social aspects, Information, Communication				
Transparent and participative decision making process				
Communication with stakeholders				
Decision support				
Necessity to use a model for decision support				

One other evaluation criteria of the LLM was whether the project had considered or not valued, relief and cultural – background and ethical values that could vary across regions (or states). Evaluation criteria defined for the LLM focused much on the environmental and socio – economic impacts of the projects and on their mitigations and compensations. The comparison of the project in the LLM was defined on the basis of the existence of an environmental and socio – economic impact assessment, the assessment of a mitigation and/or compensation plan. Other important aspects that were considered are the adoption of a monitoring plan and a water resources management plan, in order to control the achievement of the intended goal and to guarantee an equitable use of the supplied resource not only for the existing but also for future generations (Table 3).

Table 3 LLM with for the international water transfer projects



The matrix has to be read as follows: the √ symbol identifies that the problem has been considered by the project, ? identifies no sufficient information to give an answer, × identifies no consideration in the project.

The lesson learnt matrix, is the result of multi – criteria analysis of the various international IBWT projects, and provides a very useful tool to evaluate this kind of projects. This tool was applied to the Chinese case study (Fig. 5).

Description of the project. Canal 1,150 km length that connects 4 lakes to divert water from the Yangtze River to the northern region (Shandong Province). It envisages the construction of 60 pumping stations. The project is aimed to transfer 1,000 m^3/s. The project will be complete in 2020. Cost of the project: 3.74×10^9. Basic situation of the water shortage: ①Drought in the northern regions. ②Domestic, industrial, agricultural water shortage (human health problem, restriction in industrial and agricultural development ...) ③Poor domestic water quality. ④Environmental degradation (water pollution, desertification, underground exploitation and subsidence, long – term ecological disaster, sea water intrusion). Benefits of the project: ①Prevent flood in the southern region and drought in the northern region (flood control benefits). ②Expansion or improvement of agricultural irrigated area (430,000 km^2); 2.7 km^3 of supplementary water for industrial, municipal, domestic and navigational uses; development of aquatic production. ③Improve domestic water quality. ④Improve the degraded condition of environment. Socio – economic impacts. Positive impacts: ①Solve social and economical development. ②Drying of long stretches of navigable rivers. Negative impacts: ①Migration of schistosomiasis outbreak area. ②Impact of construction of the project to production and living of residents (demission of company and houses). Environmental impacts. Positive impacts: ①Increase the capacity of the water environment (storage lakes and protect the wetland ecologic environment cycle). ②Solve drought and damage of organism diversity and extinction of species. ③Decreases groundwater exploitation. Negative impacts: ①Impact of water diversion to Changjiang river estuary. ②Impact to aquatic organisms in lakes. ③Impact of sewage – retaining and diversion project to adjacent area. ④Environmental impact during the construction period (water and soil erosion). Mitigation and compensations. Socio – economical: ①Agricultural migration resettlement and house building planning (compensation for migrants that would own some basis land for living

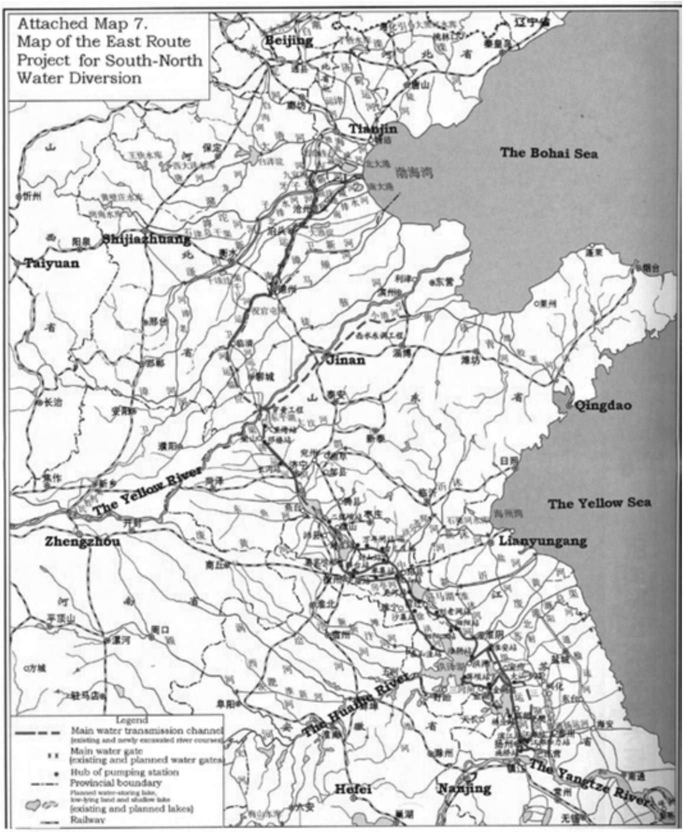


Fig. 5 The East Route of SNWTP

support) linking with economic and social development plan. ② Compensations expenses for relocation and construction of city, highway, port, communication facilities. Environmental: ①Protection measures of ecological sensitive area and resettlement of rare or severe condition species. ②Protection measure for Changjiang estuary area from salt water intrusion. ③Protection measure for workers health during construction (water, air, noise, solid waste treatment).

5 Conclusions

The East Route project is read through the use of the LLM. The LLM points out that the Chinese case study is one of the most complete of the considered studies, but it can be further improved developing a balanced plan that correlates the economic aspects to the environmental and social ones (Table 4).

It is necessary to underline the importance of careful environmental and social evaluation: since the population density and intensity of agricultural land use are much greater in the East Route project than in other international case study, both along the transfer routes and in the North China delivery region, comparable environmental impacts could have much greater repercussions on society and economy in China than in other projects. Besides, being the area of the Chinese transfer, a fundamental part of the agricultural and industrial fabric of the national economy, any effect of the transfer would be magnified in comparison to other "minor" projects: a successful transfer would contribute much more to national development, and an unsuccessful transfer would be far more detrimental.

Most important is the fundamental lesson of the Texas Water Plan that points out the need for balanced planning of the proposed transfer scheme. The Water Texas Plan, did not consider in the preliminary design phase all the environmental impacts and their related socio – economic aspects, later on, they brought a series of activities aimed at recovering all the environmental damage caused. So sustainable planning has to consider the economic and engineering system jointly to all aspects of potential environmental and social system. From a social point of view the project has to define the best water release plan along the East Route in order to meet the needs not only of the delivered region, but also of the areas along the routes of conveyance.

Table 4 LIM Matrix fox the East Route

	PROJECT
EVALUATION CRITERIA	East-Route SNDP
Technical and Economic Feasibility	
Investiment for New Infrastructures	
Benefits/costs model	
Cost recovering plan or evaluation	
Evaluation of other alternative project and/or resources management	
Prevision of future water demands for expected climate chenge	
Goal: Goals intended/Goals obtained	
Have the project reached its goals	not yet
International cooperation	
Collaboration between state and/or water agency	
Existence of treates	'
Environmental Impact Assessment	
Water quality management	
Negative impacts on ecosystem	
Positive impacts on ecosystem	
Using of model to evaluate EI	
Compensations	
Socio-economic Impact Assessment	
Using of model to evaluate socio-economic	
Negative impacts on socio-economical aspects	
Positive impacts on socio-economical aspects	
Compensations	
Ethical concepts	
Solidarity, Charity	
Sustainable management of the resources	
Risk of affecting biodiversity	
Social aspects, Information, Communication	
Transparent and partecipative decision making process	
Communication with stakeholders	
Water resource management	
Management plan of the existing water resources	'
Management plan of the supplied water resources	'
Monitoring plan	
Environmental	
Socio-economical	'

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Water Allocation and its Impact on Recipient Areas of East Route of the South – to – North Water Transfer Project

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Abstract: East Route (ER) of South – to – North Water Transfer Project (SNWTP) has miscellaneous influences on the water recipient areas. An integrated management model consisting of hydraulic, socio – economic and climate change modules is put forward to assess the comprehensive impacts caused by ER and serve as a potential decision support system in SWIMER project. This complex study is divided into hydraulic, socio – economic and climate change work groups according to the overall objective. The three special parts are relatively independent and interacted each other in terms of the framework. Several special models are selected and developed in each part with consideration of data exchange and model coupling. The methodologies and achievements obtained in this master study are presented and analyzed in this paper.

Key words: South – to – North Water Transfer Project (SNWTP), water allocation, hydraulic simulation, socio – economic impact, climate change, multi – criteria analysis

1 Background

China has very serious water problems, its per capita availability of fresh water resources accounts for barely a quarter of the world average. One obvious situation of water resources in China is the uneven distribution of precipitation and water in different areas which North China Plain accounts for 37 % of the country's total population, 45 % of cultivated land with only 12 % of total water resources, whereas South China 80 % of the direct water runoff takes place with cultivated land accounts for just 40 % of the total.

Water shortage and related eco – environmental issues in North China have become the most insurmountable barrier for sustainable development. In order to solve water scarcity in the northern region, Chinese government has evaluated a great plan to divert water from the south to the north via three routes at the upstream, middle – stream and downstream sections of the Yangtze River respectively, called the South – to – North Water Transfer Project (SNWTP). The East Route's mission is to draw water from Jiangdu, downstream of the Yangtze River, and pump water progressively northward through the historic Beijing – Hangzhou Grand Canal. The ER will be built based on some present hydraulic facilities, diverting water from the Yangtze River to the north part of Jiangsu Province passing through several lakes to enhance its capacity of regulation. Fig. 1 illustrates the deployment of ER and its water – receiving area.

The trunk of ER covers more than 1,000 km with a number of multifarious accessorial engineering, and brings comprehensive impacts on water recipient area. The construction may influence social life and environment in an area hosting more then 400 million people so that it must be developed in a sustainable way. Within the cooperation framework started in 2000, the Chinese Academy of Social Sciences (CASS) under the support of the Chinese Ministry of Water Resources and the Italian Ministry for the Environment and Territory (IMET) have organized the project of "Sustainable Water Integrated Management of the East Route in the South – North Water Diversion

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Project in China (SWIMER)". The general objective of this project is to develop an integrated river basin strategy that can optimise water resources management along the ER, and identify the rational scheme of water diversion and distribution together with the socio – economic impact on the recipient areas. Besides, absorption of advanced technology and ideology are also one goal of this project based on cooperation of both domestic and international experts.

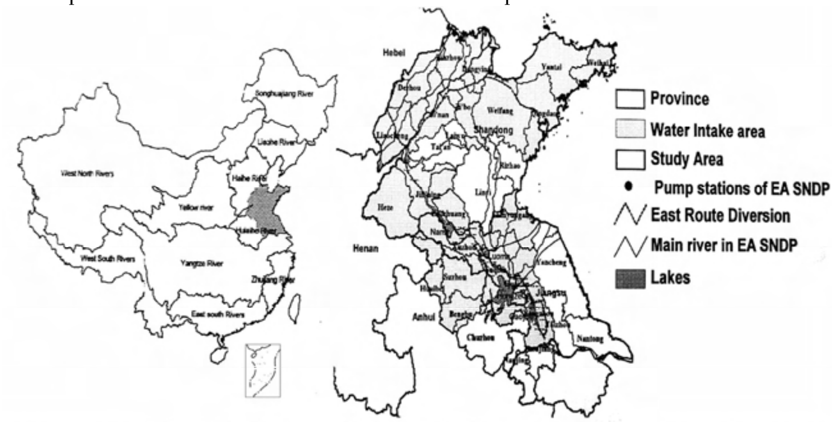

Fig. 1 Map of the study area

An integrated model that allows evaluating the multifold impacts (social, economic, environmental, and climatic) of different water diversion schemes along the East Route is the tool to realize the strategy. The socio – economic and environmental impacts of the various hydraulic scenarios will be analyzed using the model. The scenario or strategy that best balances the interests of the different stakeholders can be identified. In this paper, the framework applied and final achievements are introduced briefly.

2 Framework

The SWIMER project is divided into two phases. The first Phase is investigation and information collection, aimed at defining the domain of study area and evaluating the data necessary. The second Phase is aimed at the construction of the integrated model coupling hydraulic, socioeconomic and climate change aspects.

There are three work groups involved in this project devoted to different but mutual interacted tasks, i. e. hydraulic, socio – economic and meteorology parts. For each work group, special technical models are elaborated according to objectives of the tasks and requirements from other parts. Fig. 2 presents the general framework applied in the project. The hydraulic group develops two models for simulation of water allocation and hydraulic simulation under predefined allocation scheme. The socio – economic work group provides water demand for simulation of water allocation and assess the impact of diverted water on the recipient areas. The meteorology work group predicts the change tendency of precipitation in future based on the global and regional climate models, thus provides hydraulic group the chance to figure out the influence of climate change on water supply.

3 Methodology

3.1 Hydraulic model

3.1.1 Models selection

To ascertain the allocation scenarios of diverted water and the operation, two models are selected. The first one is ROWAS, aimed at simulation of water demand – supply balance and the other is hydraulic simulation. The water balance model will simulate the distribution of diverted water from ER among different regions under given water demand scenarios with consideration of principle to allocation and other water availability in holistic view. Then, the other hydraulic model, Res – Sim is selected to verify the feasibility of the allocation scenario based on the physical limitation of the hydraulic engineering and gives the results of optimized schemes to implement the scenarios provided by water balance model. The flowchart of interaction of the two models is shown in Fig. 3.

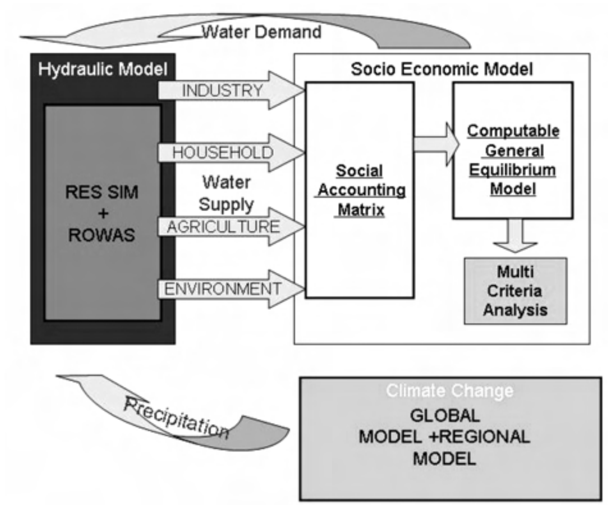

Fig. 2　Framework of SWIMER project

3.1.2　ROWAS model

ROWAS model is developed by China Institute of Water Resources and Hydropower (IWHR) to realize reasonable allocation from different water sources to various water users. It is developed by a modelling technique for water system simulation according to the macroscopic realistic process. Conceptualizations are rational hypotheses to realize the reflection from reality to the framework as a whole. In the framework, the movement and conversion of various water sources are defined. The first step to design a framework is selection and abstraction of real elements related to water resources (You, et. al, 2005). In conceptualization, various elements are represented by abstracted conceptual objects, which are described by different parameters.

There are two kinds of basic elements in the conceptual system, one is node, and the other is line. The node elements include water projects, water users, nodes of division, divarication or confluent and other control sections in watercourses. Line elements are linkages through which water moves between different nodes. Different kinds of water sources exist and move through these node or line elements and convert into each other. So there are several layers of network with links representing natural rivers, drainage of sewage, and route of water supply and discharge from the reservoirs, respectively. The simulation model is created with those conceptual objects and corresponding rules. Based on the macroscopic process in water system, a framework can be concluded, with natural water cycle and artificial process caused by human activities. The networks composed of multiple layes are designed to describe these water movements under the constraints of water balance. In the networks, a river basin or administrative region is conceptually modelled as an aggregate of normalized objects representing physical entities. Such generalized objects represent integrated water users and normalized hydraulic projects with major attributes and functions. Specific water sources moves along with possible ways defined in respective network and conversions between different water sources are described inside corresponding objects based on the mechanism existing in water cycle and exploitation. In addition, all water balance relationships are checked in the simulation process. The water cycle process can be given with prepared data information and predefined controllable parameters through this system.

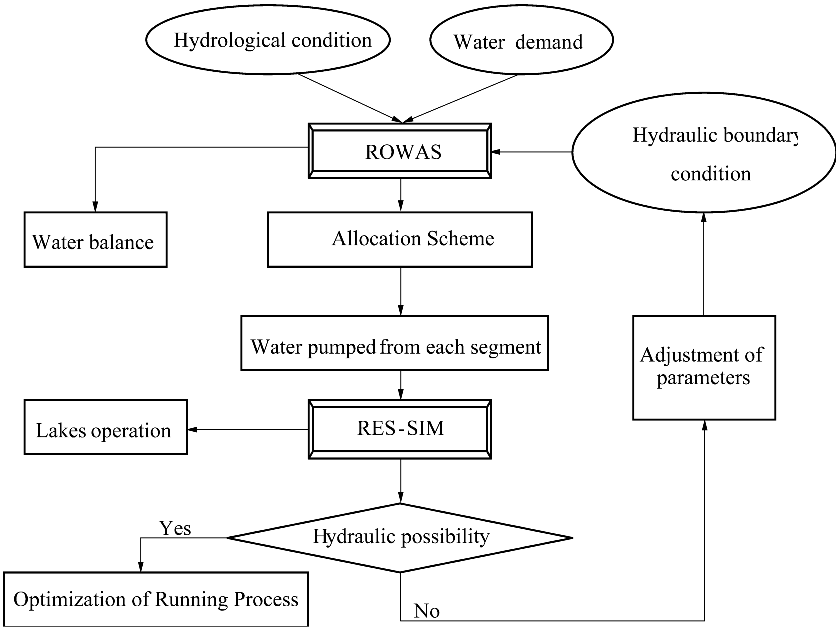

Fig. 3 Realization of integration of ROWAS and Res – Sim

3.1.3 Res – Sim Model

Res – Sim is a simulation model for reservoirs operation developed by the Hydrologic Engineering Center of the US Army Corps of Engineers. Res – Sim offers three separate sets of functions called "modules" which provide access to specific types of data within a watershed. These modules are Watershed Setup, Reservoir Network, and Simulation. Each module has a unique purpose and associated function accessible through graphic user interface.

The Watershed Setup module is to provide a common framework for watershed creation and definition among different modelling applications. A watershed is associated with a geographic region for which multiple models and area coverage can be configured. In the Watershed Set – up module, the items that describe a watershed's physical arrangement are assembled together. The purpose of the Reservoir Network module is to isolate the development of the reservoir model from the output analysis. In the Reservoir Network module, the canal network scheme is constructed; the physical and operational elements of the reservoir model are described. The Simulation module is to simulate and isolate output analysis. Once the reservoir model is complete and the alternatives have been defined, the Simulation module is used to configure the simulation. Simulated results are viewed within this module through a database file containing all records that represent the input and output for selected alternatives.

Through the Res – Sim model, users can meet the needs of real – time reservoir regulators for a decision support tool, as well as the needs of modellers doing reservoir projects studies.

3.1.4 Models interaction

The two models are developed and integrated to identify the solutions to improve ER operation. ROWAS elaborates a water balance of all the resources available in the area (surface water, groundwater, diverted water, treated sewage, etc.) and estimates the needs of diversion from the ER to minimize the water shortage. Consequently Res – Sim analyses the possibility of the network to deliver the diversion schedule according to the hydraulic situation and the operation rules. Basically, the ROWAS model is to seek water balance and macroscopic alternatives of diverted water allocation, whilst the Res – Sim is to check the possibility and find out optimal measures to realize the macroscopic scenarios presented by ROWAS. Therefore, the optimal and applicable schemes for diverted water allocation can be figured out through a combination of two such models, and provide suggestions for water management in the whole area. According to general design, the study area can be characterized by the two models (Fig. 4).

Fig. 4 Modelling of the study area from blocks and routes

With application of the ROWAS model, the water quantities from different sources allocated to different sectors with water demand are obtained for each unit. Res – Sim focuses on simulation along the line of ER. It also optimizes the amounts of water pumped from the Yangtze River according to the hydrological conditions. The connecting points of the two models are defined by the source points (intake) of every block of this conceptual model that will deliver water from the diversion. The ROWAS present water to be diverted in each segment as input of Res – Sim. ROWAS calculates in monthly time intervals and Res – Sim performs daily simulation, so the output of ROWAS will be transferred into daily data to satisfy Res – Sim requirements.

3.2 Socio – Economic Impact Analysis

3.2.1 General design

The objective of socio – economic analysis is to evaluate the impact of the East Route from the economic, social and environmental point of view. Two models are selected as the major tools based on previous studied, i.e. the Environmental Computable General Equilibrium Model (GE) and the Multi – Criteria Analysis (MCA).

Generally, CGE is applied as an assessment tool, which will allow assessing the impact on the economic, social and environmental indicators of any water allocation scheme. Then, MCA is used as an optimization tool combined with CGE to identify the optimal water allocation schemes. Joint application of above models presents the specific procedures to obtain both the assessment and the optimisation tool with indicators that have been used to evaluate the impact of the East Route. In particular, establishment of CGE Model needs: ① to specify the behavioural equations; ② to collect required information; ③ to solve the behavioural equations with respect to water uses.

Development of MCA needs: ① to define the overall objective function; ② to build a constraint maximisation problem at municipal level; ③ to construct a constraint maximisation problem at province level.

3.2.2 CGE model

The Computable General Equilibrium Model is an economic model which consists of behavioural equations for households and firms, equilibrium conditions for each single market and accounting constraints for public and foreign sectors: once calibrated according to data on the base year, it can be used to analyse the economic, social and environmental impacts of changes in exogenous variables, e. g. water supply.

The first step of application of CGE model is to specify behavioural equations, including identification of specific forms for production functions (relations which specifies the amount of inputs required to obtain a given amount of output), consumption functions (relations which specifies the amount of goods consumed in terms of prices and incomes), and equilibrium conditions (situations towards which the economy is expected to move).

The production functions for each sector depict: ① the presence of substitution between labour and capital; ② the absence of substitution between water and other production factors. To collect required information, a Social Accounting Matrix (SAM) for each affected municipality should have been developed. The study area is represented by two pilot municipalities in CGE model development due to limitation of condition and time. The model for whole area is calibrated with information of these two representative municipalities, by deriving the economic, social and environmental indicators. The selected SAM table includes followed 6 aspects: + (1) Intermediate inputs, factor levels (water, capital and labour) and production levels for agriculture, industry, and service sectors. + (2) Indirect taxes, capital depreciations and investments, for agriculture, industry, and service sectors.

(3) Domestic and foreign imports and exports for agriculture, industry, and service sectors.

(4) Profits, taxes, subsidies and savings for enterprises.

(5) Sectoral consumption, taxes, transfers and savings from rural and urban households.

Sectoral consumption, transfers, subsidies and savings from the local governmentBased on the SAM, the equation for whole system can be established, which consists of 27 equations by assuming fixed real wages. To solve the equations, all variables are converted as a function of water uses in the three sectors (agriculture, industry and service).

The solvable CGE model could assess the impact on the economic, social and environmental indicators specified above of any water allocation scheme: in other words, the analytical model can be applied as an assessment tool.

3.2.3 MCA model

The MCA model is developed to obtain optimal water allocation schemes. Therefore, the basic approaches are ascertainment of objectives and constrains. The objectives are referred to sectoral GDP, rural/urban income ratio, migration rate, employment ratio, inefficiency in water use and water pollution. The objective functions for each indicator have been finally weighted, as suggested by the multi – attribute theory version of the Multi – Criteria Analysis, in order to obtain the overall objective function. The minimization of the squared differences in percentages between the decision variable and its target value is then assumed to measure the objective function for each indicator by normalization.

The constraints are classified into 2 levels, i. e. municipal and provincial level. The solution of constraint maximisation problem at municipality level allowed to identify the sectoral water allocations, which maximises the overall objective function for each municipality discussed above. In provincial level, a constraint maximisation problem has been set to use the analytical model as an optimisation tool. In particular, a Constant Elasticity of Substitution function has been applied to the overall objective functions for each municipality in a province, in order to represent a Social Welfare function at province level. The reliance on the identity between the Atkinson inequality index and the Constant Elasticity of Substitution function, due to the simplification of constant terms in a maximisation procedure, allowed introducing an inequality aversion index into the objective function at province level.

3.3 The climate change module

Several climate models have been used and compared in this Project. In particular the adoption of different models has been driven by the fact that both global and regional climate change effects have to be considered. The global models that have been adopted are the SINTEXG and the IAP T63 while the regional model is the RegCM3. Table 1 gives out the basic description of such models.

Table 1 Comparison of climate change model used in SWIMER

MODEL	HORIZONTAL RESOLUTION	SIMULATION SCENARIOS	EXPLANATION
SINTEXG	100 km	20C3m	climate of the 20th century
		A1B	climate IPCC scenario for the 21th century
NCC/IAP T63	200 km	A1B	climate IPCCscenario for the 21th century
		A2	climate IPCCscenario for the 21th century
RegCM3	20 km	a2	climate IPCCscenario for the 21th century

In addition, several other sub – models have been used in order to evaluate parameters and data needed, and another model is design to evaluate the impact of climate change on runoff generation. SINTEX – G (SXG) model has been developed over the last few years at the Istituto Nazionale di Geofisica e Vulcanologia (INGV), with the aim of investigating the features and the mechanisms of the climate variability and change. The model is an evolution of the SINTEX and SINTEX – F models (Gualdi et al., 2003; Guilyardi et al., 2003; Luo et al.,2004).

NCC/IAP T63 is a global climate model with horizontal resolution of 1.875 by 1.875 degrees in the atmosphere and ocean. It has a vertical resolution of 16 layers in the atmosphere and 30 layers in the ocean. The NCC/IAP T63 has taken part into the inter comparison projects of the IPCC AR4 climate models. The simulations of seasonal and annual temperature and precipitation by the model for the 20th century have been reasonably compared with the observations over the globe and China (Xu et al., 2005). The simulations by other seven global climate models have been selected to provide the more evidences over the East Route of China.

The RegCM3 model has a high horizontal resolution of 20 km nest with a global climate model over China. The climate changes over China have been simulated by the RegCM3 since 2000, in order to analyze the land – use change, the effects of the different horizontal resolutions, and the impacts of the human activities. The RegCM3 has been run for 30 years (from 1961 to 1990). Simulations of the monthly, seasonal and annual mean temperature and precipitation over the East Route region are quite realistic comparing to the observations.

3.4 Models integrations

3.4.1 Climate changes and water resources

There are two aspects of climatic change effect on water resources and its exploitation. On one hand, the increase of precipitation leads to the increase of water resources. On the other hand, the water demand of agriculture decreases because of more rainfall directly use. In this study, we are more concentrated on the effect on change of water resources.

It is a complicated nonlinear process of climatic change effect to the water resources. Generally the generation coefficient under big rainfall is greater than the small rainfall. To make the influence convenient and feasible, a simple coupling analysis method is conceived based on the following two hypotheses:

(1) There is no different value in one calculating unit.

(2) The generation coefficient of water resources is invariable.

The prediction of precipitation and temperature comes from the results of the Regional Climate Model NCCT63 – A2 simulation by China National Climate Center (NCC). Distribution of water resources with and without climatic change is figured out based on the change trend of precipitation.

The climatic change data includes series from 1960 to 1990 and from 2000 to 2030. The former series is regarded as precipitation without climatic change and the last series as precipitation with climatic change.. With the hypothesis that water generation coefficient is constant, the water resources change ratio is equal to the precipitation change ratio.

3.4.2 Integration of hydraulic and socio – economic model

The evaluation of the impact of ER from the economic, social and environmental points of view will be analysed through two main tools: an assessment tool, which will allow assessing the impact on the economic, social and environmental indicators of any water allocation scheme; and an optimisation tool, which will allow to identify the optimal water allocation schemes. These two tools are characterised by different integration points with the hydraulic module. The assessment tool takes water allocations to the three production sectors, as suggested by the hydraulic module, and it evaluates the economic impacts. The optimisation tool considers the total water allocated by the hydraulic module to the three production sectors in each municipality, and seeks alternative optimal water allocations with some adjustment on allocation schemes provided by hydraulic model.

4 Achievements and conclusions

4.1 Major results

Several scenarios have been completed with consideration of hydrological, climate change issues and socioeconomic and environmental aspects. Especially during dry years the ER will be more significant, approximately 22% of the water demand is covered by the water coming from the diversion. Before the implementation of the south to north water diversion, the water shortage was faced by an intensive use of the groundwater resources. The waters provided by the East Route will permit to save groundwater resources in the impacted areas. With the ER project, the water needs for the environment can be satisfied much better due to an increased availability of local water resources.

The economic impact of ER in terms of GDP increase seems to be significant especially. The socio – economic model shows that water can create a higher value added in each municipality. Moreover the value added can be further increased if water allocation schemes for each municipality are decided at provincial level. A sensitive analysis shows the results of obtaining an increase in GDP of almost 5% if water allocation can be changed by +10% or - 10% for each municipality under fixed allocation in each province. The environmental impact of the ER has also been evaluated. The diverted water allows achieving remarkable social beneficial impacts, while investments are required to mitigate environmental impacts. Due to the diversion rural per capita income increases on average by 6.9%, while the urban per capita income increases on average by 7.1% leading to an overall benefit from a social perspective. On the other hand an overall increase in the allocated water produces an overall increase in the water pollution in industry. The environmental impact in service and agriculture sectors is not significant if compared with the industry one.

Simulation of climate changes shows the global average precipitation is expected to change with the most evident increase occurring in the northern high latitude regions, while middle latitude regions are expected to experience a decline in precipitation. Further analysis indicates that climate change is likely to accentuate the current discrepancy in water availability between the North and South of China. CO_2 doubling scenarios using global and regional circulation models predict a reduction of precipitations in the North by 2% to 15%. On the other hand the impact of Climate Change on economy seems to be very small accounting for an increase of 0.11% of the overall GDP of the Project area.

4.2 Findings and conclusions

Simulation of water allocation and hydraulic models shows:

(1) SNWTP will largely contribute to reduce the water stress in the area. The water shortages will diminish and water savings will be realised from the exploitation of the groundwater resources.

(2) The optimised allocation of the diverted water resources is compatible with the structural and operational constrains of the water diversion network under average and extreme drought conditions.

(3) An integrated management of the ER water diversion needs a centralised instrument capable of controlling the diverted water resources.

The main findings of socio – economic study could be summarised as follows:

(1) Optimization of water allocation among sectors with hydrological feasibility is necessary.

(2) Potential negative and positive impacts should be compared by specifying relative importance factors.

A stakeholder analysis shows that the government will play a decisive and irreplaceable role during the construction process. Experiences prove that the government's decision making are the key for the success of such major infrastructure construction projects.

Based on climate change study, both results from INGV and NCC global models and from the NCC regional model with different scenarios show a clear increasing trend of surface temperature in the next 100 years over most of the China region and in particular over the Eastern Route region. But the impact of climate change on water allocation is not significant, thus without effect on design of the project.

All these findings lead to the conclusion that an integrated water management is required, where information about economic, social and environmental objectives, defined in terms of indicator achievements, is combined in a real time feed – back procedure with hydrological information about feasibilities of water allocations suggested by the analytical model, and about constraints for water allocations to be considered by the analytical model.

Further, the optimisation potential could be further developed to obtain an integrated water management, where information about economic, social and environmental objectives, defined in terms of indicator achievements, is combined in a real time feed – back procedure with hydrological information about feasibilities of water allocations suggested by the analytical model, and about constraints for water allocations to be considered by the analytical model.

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Some Issues and its Countermeasures in Water Supply in Downstream of Yellow River

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Abstract: The Yellow River is a mother river of Chinese nationality. The Yellow River governance is important for national modernization, water supply is an important component of the Yellow River governance and development, and also is promising industry in economic development of Yellow River Conservancy Commission (YRCC). The Harmonious development between water supply and water usage will not only relate to economic development of YRCC, but also will promote economic development in downstream regions of Yellow River.. The paper analyses the current situations and some existing problems of water supply, and puts forward some countermeasures and recommendations, it is instructive for healthy and fast development of water supply.

Key words: Yellow River water supply, operation and management, water price, framework of water supply

The Yellow River is an important water source in northwest and north china, and it supplies water with a population of 0.14 billion, arable land of 0.24 billion Mu as well as more than 50 medium and big cities and energy sources. The amount of water per capita is 572 m^3, only accounting for a quarter of national average water quantity per capita. The Yellow River basin is of serious water shortage, socio - economic development highly depends on water supply. The development of water supply extremely promotes the improvement of agricultural production and people's living standard.

1 The current situations of the Lower Yellow River water supply

1.1 The current situations of the Lower Yellow River Irrigation District

The lower Yellow River Irrigation District refers to some irrigation areas, which situated from Taohuayu to river estuary and divert water from the mainstream of Yellow River, including some areas along the river in Henan province and Shandong province. It is situated between east longitude113°24′ ~ 118°59′ to north latitude 34°12′ ~ 38°02′. The irrigation districts are distributed along the river and their shape look like strip, and are very important production bases for grain, cotton and oil.

At present, there are 98 irrigation areas in both Henna province and Shandong province of the lower Yellow River. Each irrigation area covers an area greater than 10,000 mu. Among them, there are 11 very large irrigation districts with each covering an area greater than one million mu, 26 larger irrigation districts with each covering an area between 0.3 million to 1 million mu, 61 irrigation districts with each covering an area less than 0.3 million mu. The total planned irrigation area is 64,076 km^2, the arable land is 58.36 million mu. The total designing irrigation area is 53.69 million mu, the normal area is 36.78 million mu, the supplement area is 16.91 million mu. The effective irrigation area is 32.21 million mu, the real irrigation area is 19.75 million mu.

1.2 Status of water diverted project from Yellow River

The Yellow River culvert and sluice is referred to as water works diverting from the Yellow River, and is main water supply mouths of Yellow River water supply works. but most culverts and sluices was built in the 1980s, the design water level is the average water level corresponding to the

Yellow River design discharge of three years before construction. The Yellow River culverts and sluices not only supply water for industry and agriculture to some regions of Henan province and Shandong province along the Yellow river and the city of Qingdao ,Hebei province and the city of Tianjin, but also supply water to Zhongyuan and Shengli oil field. There are 94 water supply works in the lower Yellow River, among which, 31 and 63 water supply works are situated in Henan province and Shangdong province respectively, the design water diverting capacity is 4,400 m^3/s.

1.3 Status of water supply management

In 2006, according to implementation of water hydraulic works management system reform issued by the state council, under the principle of clear property, specific responsibility and normative management, YRCC enacted guidance to of water hydraulic works management system reform of Yellow River, and established water supply production and management system, including water supply bureau of YRCC, that of Shandong bureau, YRCC and that of Henan bureau, YRCC as well as 14 water supply subbureaus and 34 sluices management institutions under Shandong bureau, YRCC and Henan bureau. Each water supply bureau almost finished establishing some internal departments. 34 sluices management institutions became independent on river affairs bureaus of the same level, the number of staff of Yellow River water supply organizations approved by YRCC is 965, but in fact, there are 1,000 staff.

1.4 Status of water price and production and operation

According to the regulation, price administrative department and water administrative department of the state council approve the price of water supply from the lower Yellow River and inter – provincial special projects of water supply from the Yellow River. Price administrative department and water administrative department of Henan province and Shandong province approve water price of the rest water supply works. On 8th March 2005, According to the notification on adjusting water price of water supply works in downstream of the Yellow River by National Development and Reform Commission, the price of water diverted from head channel in downstream of Yellow river is as follows: The non – agricultural water is 9.2 fen/m^3 from April to June, in the other months is 8.5 fen/m^3, the agricultural water is 1.2 fen/m^3 from April to June, in the other month is 1.0 fen/m^3.

By the statistic of water diverted from Yellow River from 2001 to 2006, the annual average water amount diverted from the lower Yellow River is 6.892 billion m^3, the amount of water is 8.456 billion m^3 in 2006, and the income is 0.125 billionYuan.

2 The problem of water supply from the Lower Yellow River

2.1 Mechanism of water price establishment is unreasonable and water price is very low

After adjusting water price a few times, water price increased gradually, but it still can not meet operation, maintenance and management, resulting in serious deficit of water supply organization, and it goes against water saving.

According to principle and method of water price check by National Development and Reform Commission and Ministry of Water Resource, by analysis, the cost of agriculture water is 4.6 fen for each m^3 from April to June, in other month is 4fen; the cost of non – agricultural water is 12 fen for each m^3 from April to June,, in other month is 10.1 fen. but the actual water price is only half that of the reasonable water price, far behind the standard of cost compensation and reasonable profit. After paying staff's salary, the income from water supply only can afford partly maintenance. The maintenance owe a lot and is not safe, and to some degree affects the safe production and sustainable development of water supply.

Water price of end canal is chaotic, and lack corresponding water price policy and management, lack of water price criterion and supervision, the publicity and transparency of water price collection is poor, over water price is very serious and increase unreasonable burden of water user, occupy the water price adjustment space, affect the operation and development of water management organization . The farmer terminal water price system can not be constituted in deed. The important reason of the chaotic irrigation water charge is lacking water price management. Because the management of end canal is diverse and also relates to management of some grassroots organization, it is difficult to solve these problems by water administration sectors and price administration sectors, it is effective way to solve some existing issues in water fee collection of agriculture irrigation that water policy of high authority and strong application and strictness should be enacted as soon as possible.

2.2 The irrational water supply structure and the relative low proportion of non – agriculture

According to the amount of water diversion from 2001 to 2006, the average annual water diversion quantity is 6.844 billion m^3, agriculture water supply is 6.214 billion m^3, account for 90.8% of the total supply water, industrial and urban water supply is 6.30 billion m^3, only account for 9.2%. Compare with the proportion of non – agricultural water supply (25%) at national level, proportion of non – agriculture water supply from the Yellow River is very high, the relative low ratio of non – agricultural water supply leads to low economic benefit of water supply and is one of main reasons of deficit.

2.3 The mixture of agricultural and non – agriculture water supply, and loss of economic benefits

There are 94 water supply sluices located at the head of canal in the lower Yellow River, the canal below the head and irrigation district belong to the local sector. The sluices support agricultural and non – agricultural water supply, there is basically no such kind of sluice which only support non – agricultural water supply, most non – agricultural water supply are through canal. Due to no division between canals used for agricultural and non – agricultural water supply, this leads to non – optimum distribution of water resources, the water shortage is further serious , no division of many years between "two kinds of water" resulted in that agricultural and non – agricultural water supply coul not be measured accurately, non – agricultural water user submitted water fee according to agricultural water supply standard, this damages legal economic benefits of YRCC, and also affects the activitity of water supply organizations to some degree.

2.4 The backward water supply measuring instruments and low precision of the measurement

There are no uniform water diversion measuring standard in the downstream of the Yellow River, and the observation people are not hydrological professionals, in addition, no uniform observation criterion can be followed, the measurements and data editing are not normative and at random, resulting in large error. At present the flow meter and overflow weir are used. Due to being affected by river bed and the silt in the upstream and downstream of the sluices, the accuracy are low. This not only affects the unified water regulation of the lower Yellow River, but also causes great difficulty to the accurate calculation, optimum allocation and rational use, and also directly affects the accurate measurement of water supply, cause great damage to the economic benefits of YRCC.

2.5 The water supply project is aging and disrepairing , it is difficult to renovate and rebuild

Up to now, among the 94 sluices of downstream of the Yellow River, there are 52 sluices which have been operated for 20 years, and 29 sluices in operation for 15 ~ 20 years,. The existence and development of water supply is based on water supply works, Whether that the status of the projectis good or not directly affects the sustainable development of water supply production. Because of long – term low water price, less income and most income are used for staff salary and meet insufficient expenses of some sectors at all levels, the status of water supply works are poor, threaten water supply security and safety of flood control, inevitably affects the sustainable development of water supply.

2.6 Low rate of water supply guarantee, affects the sustainable development of water supply

The Yellow River Water supply includes the coming water, water supply, water transport, water allocation and so on, therefore, the variation in water quantity are also affected by many factors. Mainly include water supply conditions of river channel and works, local rainfall conditions, the degree of water saving application, the concerned policy and operation and management. The degree of water supply guarantee is determined by coming water and boundary and water supply works conditions, and water supply market is determined by other conditions. The coming water of river channel and variations of river channel boundary, affect water level of water supply straightly, and affect the capability of water supply, the degree of water supply guarantee decline. For example, since 2002, because the experiments of water and sediment regulation have been continuously carried out in the lower Yellow River for five years, the river channel has been hugely scoured in the lower Yellow River, this caused the adjustment and variation of river channel boundary, resulting in large decrease in water supply, some sluices even lost water diversion ability. After the water and sediment regulation in 2006, when the discharge is 3,000 m^3/s, water level decrease by 0.8 m, making most sluices diverting water very difficultly.

The decline of the guarantee ratio of water supply in downstream of Yellow River, which severely affects the activity of the people, causes the transfer and decrease of water demand. Especially the agricultural water user, under the urgent irrigation demand, if Yellow Rive water can not be supplied in time and properly, farmers turn to use well irrigation with high guarantee, and exploited and use local groundwater in large quantity. So some original channels are gradually abandoned due to being not used for long time, and further limit the utilization of Yellow River, endanger the market of Yellow River water supply. Therefore, to improve water supply guarantee is the key to ensure the healthy development of Yellow River water supply.

2.7 Lack of management and operation talents

Long time of practice in the Yellow River flood control have brought up a lot of water conservancy expert, but in the system of planned economy, lack of management and integrated talents, and the system of career – oriented limit the introduction of expert. According to the Statistics, after the reform of water supply management system in 2006, the number of staff on guard is 1,000, the framework of age is: average age is 40.2,the age below 30 is 133, between 30 to 40 is 236, between 40 to 50 is 439, and upwards 50 is 192. The framework of staff certificate is: 514 people are senior high school or below, 348 people with higher education, 132 with bachelor degree, 6 with master degree .

3 Some countermeasures and suggestions for promoting the healthy development of the Yellow River water supply

According to the current existing issues in water supply, and in combination with the planned goals, water supply during the eleventh five years plan should focus on deepening water supply management system reform , establishing and perfecting all kinds of rules, promoting water price adjustment actively, innovation of idea and water supply market development, optimum water supply structure and so on, and enhance research development, construct water supply management system, improve the measurement accuracy and water supply guarantee.

3.1 Establish water supply rules and system

Establishing and perfecting all kinds of water supply rules is one of important ways to put water supply management in order. , and enhance internal control system construction, perfect some concerned rules, and all the work should be done based on rules and legislation. Rules construction is long – term process, such as establish and perfect necessary rules and regulations, specify the relationship of water supply organizations in water supply production, finance, asset, project, administration and human resource management, and constitutes effective running mechanism. The water supply system construction should ensure water supply production stable, smooth, effective and safe.

3.2 Establish scientific and rational water price system, and gradually implement scientific water price system

Water price is the economy lever of water resource management, it can direct the water resource allocation and management, but the price of the Yellow River water supply is still low, it difficult to optimize water resource allocation. It should done carefully to analyse the content of the Yellow River water price and correctly calculate the cost of water supply production, determine different water supply price according to different situations, further perfect scientific water price system, hugely implement double water price combined basic water price with measurement water price, implement quota management of all kinds of water as soon as possible, determine rational water consumption qutao, apply over price for over qutao water consumption, actively explore new forms to water system, try to realize maximum optimum water allocation and benefit.

3.3 Develop water supply market and adjustment of water supply structure

From 2001 to 2006, the non – agricultural water supply takes up 10% in the total water supply, but the big difference between agricultural and non – agricultural water price, therefore, in order to improve economic benefits of water supply, in the future it should be centered around the concept of keeping healthy life of Yellow River, and strengthen unified water resources management and development and utilization, emphasize on the adjustment of water supply structure. On the one hand, it should promote separate agricultural water supply and non – agricultural water supply, measure agricultural water supply and non – agricultural water supply respectively, improve the accuracy of water supply measurement, increase the proportion of non – agricultural water supply, on the other hand, fully display advantages of Yellow River itself, actively develop water supply market, especially industry and urban water supply projects, increase the proportion of made water or semi – made water. The emphasis is on water supply research on the cities along the Yellow River, such as Zhengzhou, Kaifeng, Xinxiang, Puyang, Liaocheng, Bingzhou and Dongyin, and pay active attention to established and pre – establishing projects, such as coal power electricity station, metal smelting factory, and oil and chemical projects, cooperate actively with local concerned sectors, widen water market and improve economic benefits of water supply.

3.4 Strengthen construction and management of water supply project

Enhance maintenance and update of sluices, repairing a certain number of aging sluices during certain time. i. e 6 ~ 10 sluices per year, basically eliminate the hidden risk of sluices. The maintenance implement a bidding system and ensure the maintenance quality of sluices. The cost was pay from the income of water supply bureau at the provincial level. The standard for routine maintenance of sluices is mainly formulated by Water Supply Bureau of YRCC, at the beginning of annual wet period, water bureau at the provincial level and basin level check and examine routine maintenance of sluices each year, ensure the quality of maintenance.

3.5 Establish water supply information management system of downstream yellow

Along with implement Digital Yellow River Project, nowadays, at the present, 70 sluices can be controlled long distance, information can be passed from the top level to bottom level, at the same time, the information transfer network between the headquarter, YRCC and local bureau was being gradually perfected. the first term database center of the Yellow River has been finished and put into use, good infrastructure and water shortage pose higher requirement on the Yellow River water supply management. It is urgent to realize modernization of water management. Some measures should be done to promote the sustainable development of the Yellow River water supply, such as establish the Yellow River water supply management system to deepen water supply management system reform, perfecting water supply management organization, establishing automatic water supply management system and operation mechanism suitable to the Yellow River. The construction of the digital water supply management system in the downstream of Yellow River with the function of water supply production, accurate water diversion measurement, water fee collection and unified management of water supply works. The basic information database should be established to inform water quantity and quality as well as the related water policy information, and the basic situations of water works, the amount of water use and staff. Water affairs should be publicized, the digitization and automation of the routine management and water supply production should be further improved. The Yellow River water supply management should be fully improved to promote the sustainable development of water supply.

3.6 Study on increasing guarantee ratio of water supply

Nowadays, low guarantee ratio of water supply is a important factor of restricting the water supply from the Yellow River, it should increase guarantee ratio of water supply based on the unified water regulation and management of the Yellow River, one way is by reservoir regulation to increase the guarantee ratio of water supply in the downstream during water use peak time in the lower Yellow River. Another way is to study irrigation ways in the irrigation areas during water shortage period. when water demand from sluices can not met, the different ways of the sluices diverting water from the Yellow river in turn should be studied to improve water utilization. In order to improve water supply guarantee and solve some difficulties in water diversion occurred during the key water supply period, the main existing issues during all the process should be examined carefully, such as analyzing the variation in river channel cross section during the various periods, the changes in water level and discharge as well as operation situations of sluices, the capacity of water supply should be studied under different periods and discharge. analyze the water market demand and rule, study the water diverted capability of different time and different river flux, educe the key factors of affecting the guarantee ratio of water supply, and put forward countermeasure to satisfy the water demand of district along Yellow River, increase water supply benefit.

3.7 Study on the important issue and policy

According to the new status and new problem of water supply operation, it should continuously innovate and adjust the management ways and methods. Through innovation, new issues are solved and water supply development are actively promoted. Reinforce study the important issue and policy of water supply, and take the opportunity of water transfer from south to north of china and water transfer from west to east in Shandong province, combine with the problem of Dongpinghu lake, realize the breakthrough of water resource exploit.

3.8 Implement the talent development planning and strength operation and management construction

In the case of lacking high quality talents, and irrational talent structure and the low quality on the whole, the talents resources should be developed and managed, the talent development planning should be formulated and implemented, a group of high quality talents should be trained to improve the competition among the talents. Some management staff and technician should receive continuous education through training at work, self – study and training off work and so on. Strengthen the technician and workers training, a team of technicians with senior technician as backbone, middle technician as main body, matching all kinds of technicians. The required talent are employed through public employment, the evaluation and employment standard should be established with quality, capability and achievements oriented, the talent evaluation system should be different from that of the government, the encourage and restraint mechanism should be established based on examination and evaluation, in combination with responsibility, risk and achievement , short – term and long – term, physical and mentally encouragement in order to make water supply organization become home to excellent talents.

4 Conclusions

Water supply is a advantageous industry of YRCC, In order to promote the unified management, effective utilization of water resources, fully display the characteristics of water as commodity and resources, the water market should be established as soon as possible, water resources should be optimized through water market, water supply determined water demand, fully display the role of water price, and protect water resources by rational water price. the perfect water market and rational water price should be established as soon as possible.

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A Study on Capacity Evaluation of Sustainable Water Supply Development in the Lower Yellow River

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Abstract: Sustainable development of the Yellow River water supply is a complicated and integrated system, and it is an important component of maintaining healthy life of the Yellow River. This paper established evaluation index system of water supply in the downstream of the Yellow River from multiple targets. In order to determine the weight of evaluation index in a reasonable way, it also discussed the process of taking Analytic Hierarchy Process (AHP) as a method of computing weight of evaluation index. And Accelerating Genetic Algorithm (AGA) was used to correct a consistency of judgment matrix and calculate ranking weights of judgment matrix, which is AGA – CAHP. The results suggested that AGA – CAHP is visual, simple, stable , accurate, and applicable in practice.
Key words: the Yellow River water supply, sustainable development capacity, evaluation index, Analytic Hierarchy Process (AHP), genetic algorithm

The Yellow River is a mother river of Chinese nationality. TheYellow River governance is important for national modernization, water supply is an important component of the Yellow River governance and development, and also is the promising industry in economic development of the Yellow River conservancy commission (YRCC). The Harmonious development between water supply and water usage will not only relate to economic development of the Yellow River Conservancy Commission, but also will promote economic development in the downstream regions of the Yellow River. However, many issues exist at the current the Yellow River water supply development.

Sustainable development of the Yellow River water supply had attracted common attention from the downstream regions of the Yellow River. As a backbone industry of YRCC, water supply is also very important for the sustainable socio – economic development of the downstream regions of the Yellow River. It plays a vital role in the sustainable development of the downstream of the Yellow River. The sustainable development of Yellow River water supply was analyzed in this paper by Analytic Hierarchy Process (AHP).

1 The sustainable development system of the Yellow River water supply and its content

The sustainable development system of Yellow River water supply refers to a comprehensive system under the instruction of sustainable development theory, which takes water source, water works, the way of water usage as well as water supply management as a whole, and takes resources, environment and technical development as constraints. This system centers around human being and targets on the realization of sustainable development.

The assessment on whether water supply is sustainable or not , includes the following two contents. One is to assess sustainability of water supply development during the past different periods, the other is to predict that whether the development of the future water supply will arrive the sustainability.

2 The improved AGA – CAHP of evaluation on sustainable development of the Yellow River water supply

The main issues of the application of Analytical Hierarchy Process (AHP) in practice are how to verify and modify the consistency of judgment matrix and how to calculate the rank weights of elements in AHP. The main issues such as high subjectivity, uninsured optimization for the original judgment matrix by modifying criteria, and modification being restricted only to special elements in judgment matrix, exist in the present methods. There is not any uniform modification mode to this day. The modification is accomplished generally by experiences and skills in the application of AHP, without corresponding scientific theories and methods. This paper considers AHP as a method determining index weights and modifies the consistency of judgment matrix with the Accelerating Genetic Algorithm (AGA). The rank weights of elements in judgment matrix are calculated with the AGA – CAHP method. The following is the procedure of applying this method to the evaluation on the system of sustainable development of Yellow River water supply:

Step 1. The first step is to set up the hierarchy structure model according to the property and requirement of the problems. The model consists of three levels that are named from up to down as: target level A, domain level B, and project level C. Level A is the total target of the system concluding only one element named as sustainable development of Yellow River water supply. Level B describes n number of domains used for describing total target. Level C concludes m number of projects describing both total target and all domains. These targets, domains and projects in each level are all called system elements.

Step 2. In this step it is required to employ the pair – wise comparison of relative importance to the elements of Level B or Level C, of which the criteria depend on its higher level. With scale 1 ~ 9 the judgment matrix of Level B can be obtained as: $B = \lfloor b_{ij} \mid i,j = 1 \sim n \rfloor_{n \times n}$, where b_{ij} is the relative importance of influence from element B_i to element B_j in view of the total target A. The judgment matrix of Level C corresponding to element B_k of Level B is:

$$\lfloor c_{ij}^{k} \mid i,j = 1 \sim m; k = 1 \sim n \rfloor_{m \times m}$$

Step 3. After determining the rank weights representing the relative importance of elements of one level to that of the higher level, verification and modification of the consistency of each judgment matrix can be achieved. With setting the rank weights of elements of Level B as $w_k, k = 1 \sim n$, the conditions $w_k > 0$ and $\sum_{i=1}^{n} w_k = 1$ are satisfied. According to the definition of B, the following equation becomes theoretically true: $b_{ij} = \dfrac{w_i}{w_j} \quad (i,j = 1 \sim n) \cdots$ (1)

In this instance there are such characteristics of the matrix B as: ①judgment matrix being unit: $b_{ii} = \dfrac{w_i}{w_i} = 1$; ②judgment matrix being reciprocal: $b_{ji} = \dfrac{w_j}{w_i} = \dfrac{1}{b_{ij}}$; ③judgment matrix being consistent: $b_{ij} b_{ji} = \dfrac{w_i}{w_j} \cdot \dfrac{w_j}{w_k} = \dfrac{w_i}{w_k} = b_{ik}$.

With the known judgment matrix $B = \lfloor b_{ij} \rfloor_{n \times n}$, the single rank weights $[w_k \mid k = 1 \sim n]$ can be calculated. If the judgment matrix B meets Eq. (1), decision makers can accurately measure w_i / w_j, $b_{ij} = w_i / w_j$ and the complete consistency of the judgment matrix B can be reached, then it can be obtained as:

$$\sum_{i=1}^{n} \sum_{j=1}^{n} \mid b_{ij} w_j - w_i \mid = 0 \qquad (2)$$

Actually, because of the complexity of real system, the diversity, unilateralism and instability of people's cognition, there is not any unified and exact ruler for measuring the importance of system elements. It often happens in practice that the consistency of judgment matrix B is not reached. The AHP method requires only satisfied consistency of judgment matrix in order to fit various complex systems in the real world. The judgment matrix should be modified if its consistency can not be met. Setting the modified judgment matrix of B as $X = \lfloor x_{ij} \rfloor_{n \times n}$, and the single rank weights of elements of X being written as $[w_k \mid k = 1 \sim n]$, the matrix X that can minimize the following equation can be named the optimal consistency judgment matrix.

$$\min CIC(n) = \sum_{i=1}^{n} \sum_{j=i}^{n} \mid x_{ij} - b_{ij} \mid / n^2 + \sum_{i=1}^{n} \sum_{j=1}^{n} \mid x_{ij} w_j - w_i \mid / n^2 \qquad (3)$$

s. t.

$$\begin{cases} x_{ij} = 1 \quad (i = 1 \sim n) \\ 1/x_{ij} = x_{ji} \in \lfloor b_{ij} - db_{ij}, b_{ij} + db_{ij} \rfloor \qquad (i = 1 \sim n, j = i + 1 \sim n) \\ w_k > 0 \qquad (k = 1 \sim n) \\ \sum_{k=1}^{n} w_k = 1 \end{cases}$$

where the object function $CIC(n)$ means the consistency index coefficient; d is a non – negative parameter allowed selecting in the scale of [0,0.5], other variables means the same as before. Eq. (3) represents a non – linear optimization problem, in which the optimization variables are the single rank weights w_k and the elements in the upper triangular part of the modified judgment matrix X. There are $n(n+1)/2$ number of independent optimization variables for the n – rank judgment matrix B. Obviously, the left value of Eq. (3) becomes smaller, the consistency of judgment matrix B becomes higher. When the global minimum $CIC(n) = 0$ is obtained, $X = B$, Eq. (1) and Eq. (2) become true, which means at the same time that the complete consistency of the judgment matrix B has been reached. It is also known that this global minimum is unique according to the constraint $\sum_{k=1}^{n} w_k = 1$. The Accelerating Genetic Algorithm (AGA) is a general global optimization method, which makes the calculation of problems represented by Eq. (3) easyly and effectively. When the value of $CIC(n)$ is less than a standard value, it can be considered as the satisfied consistency of the judgment matrix B has been reached and the single rank weights w_k of elements calculated with this matrix are acceptable. Otherwise, parameter d should be increased until the satisfied consistency is reached. similary, the single rank weight of the k element of level B related to each element of level C and the corresponding consistency indexes $CIC^k(m), k = 1 \sim n$ can be determined by the judgment matrixes $\lfloor c_{ij}^k \rfloor_{n \times n}$ of level C.

When the values of $CIC^k(m)$ are less than the standard value, it can be considered that the satisfied consistency of the judgment matrixes $\lfloor c_{ij}^k \rfloor_{n \times n}$ have been reached and the single rank weights w_i^k of elements calculated with those matrixes are acceptable. Otherwise, the judgment matrixes should be adjusted until the satisfied consistency is reached.

Step4. At this step it needs to determine the rank weights of all elements of the same level related to the highest level A and to test the consistency of each judgment matrix. This process should be realized from the highest level to the lowest level one by one. The single rank weights w_k $(k = 1 \sim n)$ and consistency indexes $CIC(n)$ of elements of level B are also the global rank weights and global rank consistency indexes of level B at the same time. The global rank weights of level C are $w_i^A = \sum_{k=1}^{n} w_k w_i^k (i = 1 \sim m)$, and the global rank consistency indexes are $CIC^A(m) = \sum_{k=1}^{n} w_k CIC^k(m)$. When $CIC^A(m)$ are all less than a standard value, it can be considered that the satisfied consistency has been reached by ranking process and the global rank weights w_i^A of elements calculated on this condition are considered acceptable. Otherwise, the corresponding judgment matrixes should be adjusted until the satisfied consistency is reached.

Step 5. It is required to accomplish classifying and ranking according to the global rank weights $w_i^A (i = 1 \sim m)$ of elements of level C, which will be the basis of evaluation of system of sustainable development of Yellow River water supply.

3 Study on evaluation of sustainable development capacity of Yellow River water supply

3.1 Selection of evaluation indexes and establishment of index system

Setting up Evaluation Index System of sustainable water supply development should be based on the strategic objectives and instructive ideas of sustainable water supply development, and combined with its characteristics in order to choose proper evaluation index.

3.1.1 Principle of selecting e valuation indexes

(1) Particularity;
(2) Synthesis;
(3) Practice.

3.1.2 Establishment of index system

The index system is established as follows according to the content of sustainable water supply development and the principle of selecting evaluation indexes. This system includes four subsystems: water source, water works, water use method and water supply management. Setting up detailed indexes and the subsystems are shown in Fig. 1.

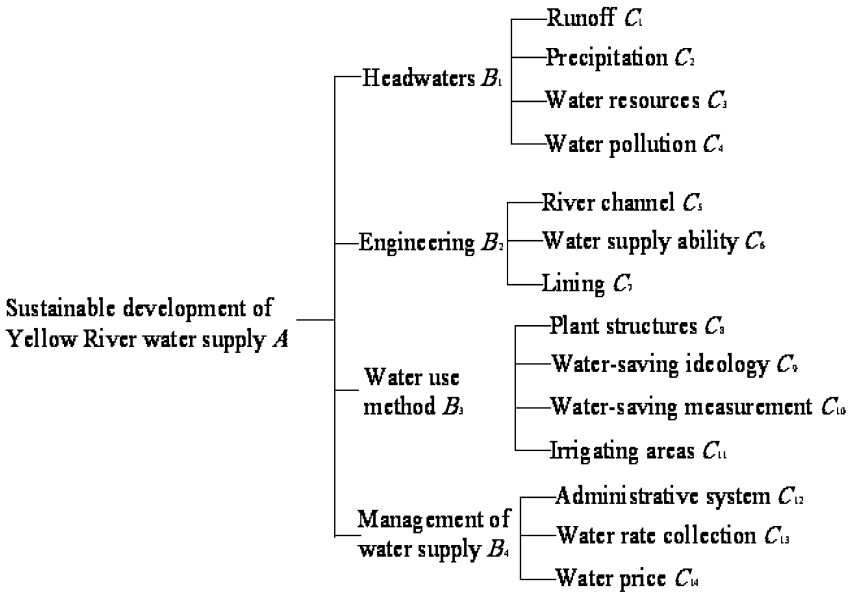

Fig. 1 Evaluation index system of sustainable development capability of the Yellow River water supply

3.1.3 Evaluation on sustainable water supply development of the Yellow River

In terms of water supply in the downstream of the Yellow River, the five judgment matrixes can be obtained by consulting experts and giving a value to the importance with scale 1 ~ 9, just as shown in Table 1:

$$A=\begin{bmatrix}1&3&5&4\\1/3&1&4&3\\1/5&1/4&1&2\\1/4&1/3&1/2&1\end{bmatrix},B_1=\begin{bmatrix}1&3&3&5\\1/3&1&3&6\\1/3&1/3&1&3\\1/5&1/6&3&1\end{bmatrix},B_2=\begin{bmatrix}1&3&5\\1/3&1&4\\1/5&1/4&1\end{bmatrix}$$

$$B_3=\begin{bmatrix}1&2&2&2\\1/2&1&2&2\\1/2&1/2&1&2\\1/2&1/2&1/2&1\end{bmatrix},B_4=\begin{bmatrix}1&2&1\\1/2&1&1\\1&1&1\end{bmatrix}$$

Table 1 The meaning of the number 1 to 9

Value	Meaning
1	i and j being of the same importance
3	i being slightly more important than j
5	i being a bit more important than j
7	i being much more important than j
9	i being absolutely more important than j
2,4,6,8	Values corresponding to the middle states between each pair of neighbored judgments

After calculating the rank weights of judgment matrixes with AGA – CAHP method, the results are showed in Table 2.

Tab 2 Results of rank weights of judgment matrixes by using AGA – CAHP

Judgment matrix	Rank weight				Coefficient of consistency index
	w_1	w_2	w_3	w_4	
A	0.534,0	0.271,4	0.107,9	0.086,7	0.075,9
B_1	0.494,2	0.298,6	0.145,0	0.062,3	0.080,8
B_2	0.626,7	0.279,7	0.093,6		0.073,9
B_3	0.390,5	0.276,1	0.195,3	0.138,1	0.044,9
B_4	0.412,6	0.259,9	0.327,5		0.046,2

It is known from Table 2 that the consistency coefficients of these judgment matrixes are all less than 0.10, which indicates the satisfied consistency is reached. Moreover, the global rank weights of indexes $C_1 \sim C_{14}$ of level C are: (0.267,3,0.161,5,0.078,4,0.033,7,0.163,4,0.072,9, 0.024,4,0.043,1,0.030,5,0.021,6,0.015,3,0.036,2,0.022,8,0.028,8), and the global consistency index is 0.072,7, less than 0.1, which indicates the satisfactory consistency of each judgment matrix is reached. The above obtained global rank weights can be used as the weights of each evaluation index of sustainable water supply development of the Yellow River.

3.2 Result analysis

It can be seen from the above results that: the most influential indexes on headwaters are runoff and precipitation; the top two influential factors on engineering are river channel and water supply ability; the most influential indexes on water use methods are plant structures and water – saving awareness; the most influential indexes on water supply management are administrative management system and water resources fee collection. The results also show that the top seven influential indexes on sustainable development of Yellow River water supply are runoff, river channel, precipitation, water resources, water supply ability, plant structures and administrative management system.

4 Conclusions

Evaluation on sustainable water supply development of the Yellow River was complicated, hierarchy system which included many indexes. The crux is how to determine weight of index reasonably. For this, this paper discussed that Analytic Hierarchy Process (AHP) was applied to compute weight of evaluation index. Accelerating Genetic Algorithm was utilized to ameliorate consistency of judgment matrix and calculate rank weights of judgment matrix, which is AGA – CAHP. The results suggested that AGA – CAHP is stable and accurate, which can be applied in practice.

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Estimation Study on Agriculture Water Requirement in Irrigation Area for Careful Regulation of Water Resources of the Yellow River

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Abstract: The four irrigation areas, Ningxia, Inn – Mongolia, Henan and Shandong Provinces (municipality), are the main agriculture farmland for fine regulation of water resources of the Yellow River. It is important to establish water requirement evaluation model for predicting agriculture water requirement in the irrigation areas during water dispatching in the Yellow River. Water requirement analysis during growth of paddy and drought – crop was given in this paper and main effecting factors were discussed for water demand of irrigation area. An evaluation model was proposed integrating with calculation of crop water requirement, soil surface water content and soil moisture distribution on vertical aspect for synthetically considering the factors of account weather, crop and land hydrology course, irrigation requirement and soil moisture status to predict water requirement in the irrigation areas under different weather condition and different irrigated flux. Furthermore, water regulation of the Yellow River can be calculated and simulated combining with the analysis of weather condition and crop water requirement of irrigated area in the future. This paper will provide a method for calculating irrigation requirement for water regulation of the Yellow River based on remote sensing monitoring technology.

Key words: water regulation of the Yellow River, water requirement model, remote sensing

1 Introduction

In order to optimize water allocation in the Yellow River, improve water resource utilization efficiency and mitigate water carrying – pressure, fine regulation of water resources of Yellow River was prompted by Yellow River Consenancy Commission(YRCC). Agricultural water occupies above 80% of the whole water resource of the Yellow River, in which four irrigated areas of Ningxia, Inner – Monglia, Henan and Shandong are the main users, which is the emphasis for water fine regulation of the Yellow River.

Agricultural water use was affected mainly by precipitation and weather factors, and it has a close correlation with soil moisture. Irrigation requirement is determined by weather condition and crop factors. Water fine regulation in irrigated area was decided by irrigation requirement and runoff condition from the upper reach. Now reservoirs such as Longyangxia, Liujiaxia, Wanjiazhai, Sanmenxia and Xiaolangdi are used in water regulation of the Yellow River to adjust water quantity. For it will last a long time on the upper reach to regulate water to irrigation areas, so irrigation requirement should be estimated precisely previously. If the estimated water requirement greater than its actual demand, water will be abandoned which will cause water wasting, If the estimated water requirement less than its actual demand, water requirement can not be satisfied. Under this condition, irrigation requirement estimation model should be developed to estimate water requirement in irrigated area, which is the key issue of fine regulation of water resources in the Yellow River Basin.

2 General conditions and water requirement study status in the irrigation area

2.1 General conditions of the irrigation area

Hetao Plain is the biggest irrigation district of Yellow River basin in northern china, which indudes Ningxia irrigated area and Inner – Monglia irrigated area. In Ningxia irrigated area, there are 17 main trenches, 4.09 million mu of designed irrigation area and 4.42 million mu of effective irrigation area. The multi – annual average water diversion is 75.67 ~ 80.13 hundred million stere. The actual net water consumption of the Yellow River is 32 hundred million stere per year. In Inner – Monglia irrigated area, there are 13 main trenches. The multi – annual average water diversion is 61.95 hundred million stere. The water consumption is 50.03 hundred million stere. The irrigation season was concentrated on from the middle of April to November, and the net water diversion from the Yellow River is 47.44 hundred million stere per year subtracting the water diversion of 2.59 hundred million stere from Wuliangsuhai.

The irrigation districts on the lower Yellow River(Henan irrigated area and Shandong irrigated area) is the biggest irrigation area in china. The designed land area is 6.408 ten thousand square kilometer. The farmland is 58.36 thousand mu and the fact irrigated area is 3.143 ten thousand mu since 1990s. There are 16 cities with 87 comties(district) in Henan and Shandong Province. The total population benefits from it is 55.41 thousand. The irrigation area in the Lower Yellow River is the important grain and cotton production bases in China, which will do great action to the development of economic to the shores in the Lower Yellow River.

2.2 Study status on water requirement

Water allocation mainly depends on irrigation requirement, which is the basis of water regulation of the Yellow River. Now the study on water requirement can be classified into two classes: one is crop water requirement method (Li Qusheng etc., 2004); the other is water balance method within irrigated area (Qing Dayong etc.,2003; Wu Ning xia etc., 2006). With first, water requirement for farmland was considered as same as crop water requirement, through analysis crops water requirement. Reference crop transpiration (ET_0) is the mainly considered factors combining weather data and crop pattern within irrigated area. With second method within irrigated area, water balance model was established based on dynamic water requirement calculation according to water requirement during the course of crop growing, water consumption mechanism and water circle rule.

Crop water requirement method: it can also be called FAO56 method (Allen R G, etc., 1998). Its calculation formula is shown as following:

$$ET_c = (K_{cb} + K_e) ET_0 \tag{1}$$

where, ET_c is crop water requirement (mm/d); K_{cb} is crop coefficient; K_e is soil evaporation coefficient; ET_0 is reference crop transpiration (mm/d).

It is considered that crop water requirement is mainly affected by weather condition, soil moisture and crop in nature. ET_0 reflects weather condition; K_e reflects soil water condition; K_{cb} reflects crop growth condition. Existing studies show that the key issue to apply this method is to acquire a great number of water moisture observing data in the irrigation area.

Water balance method: The model was established with the support of a great number of data, including patch area of net irrigation requirement for crops, gross irrigation requirement, crop directly recharging from groundwater, recharging to farmland from infiltration, recharging from infiltration of canal system, shallow water evaporation and soil surface water evaporation. Water balance method has a specific physical definition, but it needs a great deal of data with very complex data process.

Now irrigation requirement calculation for farmland has harvesting theory, but many studies should be done when put it into practice for a great number of soil moisture and evapotranspiration data needed. Based on crop water requirement, considering land surface hydrology course, this paper proposed a research thought about irrigation area water requirement linked to remote sensing monitoring.

3 Analysis of water requirement calculation

Main crops planted in the Yellow River basin are paddy and drought – crops. Different kinds of crop have different water requirement at their different growing stage. Therefore, two methods should be considered at the same time. Irrigation requirement should consider either water requirement before sowing or during crop growing.

3.1 Water requirement in irrigated area

Water for irrigation in the irrigated area in the Yellow River basin are extracted from surface water and ground water. Irrigated water requirement (W_Y) can be represented as follow:

$$W_Y = \frac{Q - W_L \eta_L}{\eta_0} \tag{2}$$

where, W_L is ground water resource in local area, often can be obtained from some related department; Q is crop – field irrigated water requirement on irrigated area; η_L is the irrigated water use coefficient of ground water, can be confirmed by experience; η_0 is the coefficient of the Yellow River water use, can be confirmed by experience.

Crop – field water requirement in irrigated area is decided by paddy and drought – crop water requirement of its growth period or the prophase of planting. It can be represented as follow:

$$Q = F(m_r, m_{rt}, m_b, m_{at}) \tag{3}$$

in which, Q is irrigated water requirement; m_r is paddy water requirement before planting; m_{rt} is paddy water requirement during its growth; m_b is drought – crop water requirement before planting; m_{at} is drought – crop water requirement during its growth.

3.2 Irrigation requirement of paddy field

3.2.1 Water requirement for steeping field for transplanting rice

Paddy irrigating include two stages, one is the irrigation before its planting, the other is the irrigation after transplanting rice seeding. It can be calculated by the following formula:

$$m_r = h_0 + S_1 + e_1 t_1 - P_1 \tag{4}$$

in the formula, m_r is the irrigated water for steeping field for transplanting rice; h_0 is the depth of designed water layer when transplanting rice seeding; S_1 is the seepage before planting; t_1 is the days of steeping field for transplanting rice; e_1 is surface – water daily mean evaporation identity during t_1; P_1 is the precipitation during t_1.

Usually, irrigating quota is calculated by soil, topography, subsoil water depth and farming depth.

3.2.2 Water requirement on rice growth stages

At either crop growth stage, paddy filed irrigated water can be calculated according to water quantity equation, that is:

$$m_{rt} = (h_2 - h_1) + W_C + d - P \tag{5}$$

in the formula, h_2 is field water layer depth at the final period of time; h_1 is field water layer depth at first period of time; W_C is field water wastage within the period of time; d is drainage within the period of time; P is the rainfall within the period of time.

3.3 Irrigation requirement of drought – crop field

3.3.1 Pre – seeding irrigation

The crop – field must be irrigated in order to satisfy the requirement of soil water for germinating and burgeoning. Usually the crop – field will be irrigated only once time before planting. The irrigated time is related to local planting custom, weather condition and soil condition.

$$m_b = H(\theta_{max} - \theta_0) n \tag{6}$$

in the formula, m_b is irrigating ration before planting; θ_{max} is field capacity, which can be selected by some related test data; θ_0 is the average water content of H soil layer before planting; n is soil porosity, which is the percent of soil volume.

3.3.2 Irrigation on drought – crop growth stages

Water irrigation on drought – crop growth stages can be calculated using soil water balance equation, which is shown as follows:

$$m_{at} = \Delta W_t + ET_t - W_r - p_0 - K \tag{7}$$

in the formula: ΔW_t is the change of soil water – storage capacity within time t, which was calculated by soil monitoring data; ET_t is the crop water requirement ET_c within time t, or it is the actual Evapotranspiration within time t; W_r is the increasing quantity of designed moisture layer of soil; p_0 is the effective rainfall storage within designed moisture layer of soil; K is rechargeable water amount to groundwater.

3.3.3 Crop water requirement ET_t

The crop water requirement ET_t is decided by reference crop water requirement ET_0. means crop transpiration under sufficient soil water, surface – land completely covered, crop growth normally, short grass land (great than 200 m both in length and width) nearly under the same condition (grass is 8 ~ 15 cm in height). Because reference crop water requirement ET_0 is mainly under the influence of weather condition, it can be calculated by stages according to local weather condition data. ET_0 can be calculated using the following formula.

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{t + 273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \tag{8}$$

in the formula, ET_0 is reference crop water requirement, mm/d; Δ is slope of saturation vapor pressure and air temperature curve; R_n is net radiation for the surface of crop coronal layer, MJ/(m^2 · d); G is soil heat flux, MJ/(m^2 · d); γ is psychrometric constant, kPa/℃; u_2 is the mean daily air temperature at 2 m height, ℃; ($e_s - e_a$) is vapour pressure deficit VPD, kPa.

Crop water requirement ET_t can be calculated through correcting ET_0 with crop coefficient K_c and soil coefficient K_s.

$$ET_t = (K_s + K_c) ET_0 \tag{9}$$

$$\begin{cases} K_s = \dfrac{\ln(A_v + 1)}{\ln(101)} \\ A_v = \dfrac{W - W_m}{W_f - W_m} \end{cases} \tag{10}$$

$$K_c = \alpha \times LAI^{\beta} \tag{11}$$

in the formula, W is the mean water content of soil at the specified time; W_m is wilting coefficient; W_f is field moisture capacity; LAI is leaf area index; β is experience coefficient. According to a new study, in the equation (6), (10), (11), LAI, W and θ_0 are very important data when calculating water irrigation and they are hard to be obtained in practice. A new approach was presented to obtain these data based on remote sensing technology for the water requirement model study in irrigated area.

4 Water requirement estimation model in irrigating region

Based on remote sensing technology, water requirement estimation model was established with the analysis water requirement of paddy and drought – crop. The model can be used to analogy and calculate soil water content condition combining with weather and hydrology methods. The model is composed of crop water requirement, surface – water soil water content and soil humidity distribution on vertical scale etc. , as shon in Fig. 1. The model predicts water requirement and soil moisture status in farmland under different weather conditions and different irrigating conditions during irrigation time. Yellow River water resources regulation will be calculated with the analysis of future weather conditions and crop water requirement. Irrigation requirement model not only can be used to guide the drawing of water regulation scheme, but also can be used to quickly modify water regulation scheme of the Yellow River.

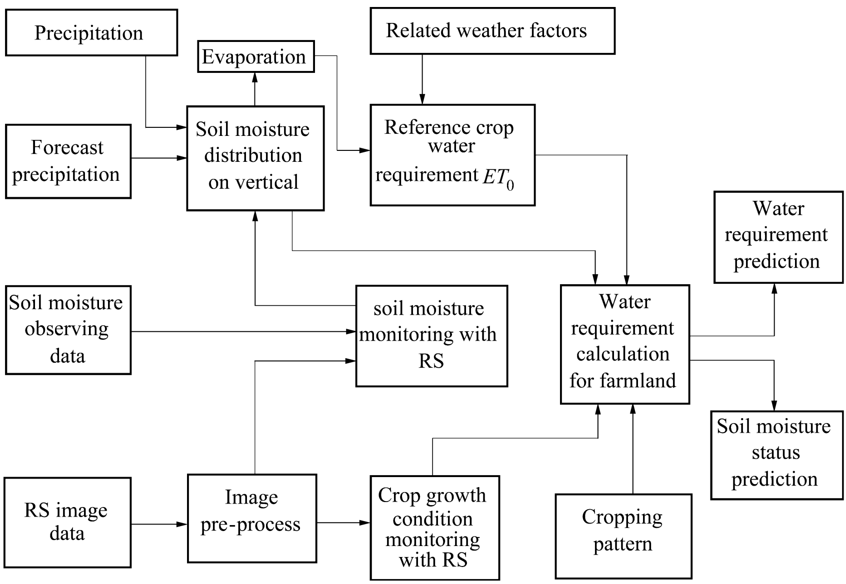

Fig. 1 Irrigation requirement estimation model composing

The essential data used which take part in model calculation are remote sensing images, soil humidity observing data, precipitation and other weather data. These data can be got quickly with remote sensing monitoring model. Soil humidity observing data and weather data are used to determine parameters in the model and to test it. Remote sensing images include multi – spectrum image, SAR and weather satellite data. Crop condition is monitored using multi – spectrum; surface – soil water content is monitored using three kinds of images, in which weather satellite image with low spatial resolution is used to macro – region monitoring and SAR and multi – spectrum data with higher resolution is used to farmland scale monitoring.

In irrigation requirement estimation model, reference crop water requirement (ET_0) only has the relation with weather condition. Crop condition (LAI) is easy to be obtained with images. The calculation methods of surface – soil water content and soil humidity distribution on vertical scale are discussed in details as follows.

4.1 Surface – soil water content calculation using RS

Soil water content was calculated using optical, thermal and microwave remote sensing. Thermal Inertia (*TI*), Crop Water Stress Index (*CWSI*), Departure Vegetation Index (*DVI*) Thermal Infrared remote sensing monitoring method were usually employed to soil water contend monitoring(CHENG Huai – liang etc. ,1999). According to their principles, Thermal Inertia(*TI*) and Crop Water Stress Index(*CWSI*) models could be used on soil water content monitoring in the Yellow River.

Thermal Inertia: *TI* is one heat characteristic of soil, which is the intrinsic factor arousing temperature variation on surface – soil. *TI* is close to soil water content, and it controls soil temperature daily range. Soil temperature daily range can be obtained using remote sensing technology, which makes it possible to monitoring soil water content with image, especially with NOAA/AVHRR data. In practical application, Apparent Thermal Inertia(*ATI*) always replace *TI*.

$$ATI = \frac{1 - A}{T_d - T_n} \tag{12}$$

in the formula, T_d, T_n are temperatures of day and night respectively, each can be separately calculated with radiation normalization of four bands in day and night. A is panchromatic albedo, which can be calculated with reflectance of band1 and band2. Soil water content W can be calculated with the following experience formula when ATI has been reckoned, that is:

$$W = a \times ATI + b \tag{13}$$

Crop Water Stress Index (*CWSI*): *CWSI* is calculated with crown surface temperature (Tc), surrounding air temperature (Ta) and solar net radiation, which reflect the ratio of crop evaportranspiration to the maximum evaporation. Crop Water Stress Index (*CWSI*) can be connected with daily average evaporation at the homogeneous condition, which can be a factor using estimation soil water condition of crop root layer. Crop Water Stress Index (*CWSI*) is defined as follows:

$$CWSI = \frac{\gamma[1 + r_c(r_{ac} + r_{bh})] - r/\Delta + \gamma(1 + r_c)}{(r_{ac} + r_{bh})} \tag{14}$$

$$r = \gamma[1 + r_{cp}/(r_{ac} + r_{bh})] \tag{15}$$

in the formula: γ is dry – wet bulk constant, Pa/℃; r_{ac} is rectified aerodynamic drag, s/m; r_{bh} is residual resistance, s/m; r_c is crop canopy resistances, s/m; Δ is slope of saturation vapor pressure and air temperature curve; r_{cp} is potential canopy resistances of evaportranspiration, s/m.

4.2 Soil moisture vertical distribution

Soil humidity distribution on vertical aspect is an important index for evaluating water deficit in crop, and it is determined by soil infiltration condition. Soil infiltration affecting factors include soil texture, initial water content of soil, soil crust, rainfall, soil – plant underlying surface, irrigation method and air temperature etc. (Su Fengge etc., 2001).

Flood irrigation was usually adopted at irrigation season in the Yellow River basin. According to water motion characteristic, runoff generation calculation should contain two parts: one is soil surface runoff and the other is soil – layer flow(Liu Xian zhao etc. ,1999). Comparison of two – impact runoff generation method, vertically – mixed runoff model is more suitable than Xin'anjiang model for calculation runoff generation in Yellow River irrigated area(Qu Si min etc., 2003). In the vertically – mixed runoff model, soil surface runoff is a Horton mode, which is determined by rainfall intensity and initial soil moisture; Subsoil runoff, including soil layer flow and groundwater runoff, is a Dunne flow mode, which is determined by initial soil moisture and actual infiltration. On the calculation of vertically – mixed runoff, the proportion of Dunne flow and Horton flow are changing with initial soil moisture and actual infiltration. The formula is represented as follows:

$$a = 1 - \left(1 - \frac{F_A + a}{W_{mm}}\right)^B \tag{16}$$

in the formula: a is coefficient of proportion for Dunne flow; F_A is actual infiltration; W_{mm} is the maximum water storage capacity; B is distribution curve index of water storage; is the Y – axis value corresponding to W, the initial average soil water content.

Vertically – mixed runoff calculation was divided into two parts: soil surface runoff and groundwater runoff. Land – surface runoff R_S belongs to Horton flow, which is calculated with Green – Ampt infiltration curve with basement characteristic. The formula is an follows:

$$F_M = F_C\left(1 + K_F \frac{W_M - W}{W_M}\right) \tag{17}$$

$$\begin{cases} F_A = F_M & P \geqslant F_M(B_F + 1) \\ F_A = F_N\left(1 - \dfrac{P_E}{F_M(B_F + 1)}\right)^{B_F + 1} & P_E \pi F_M(B_F + 1) \end{cases} \tag{18}$$

in the formula, F_M is average soil infiltration capacity in drainage area; F_C is steady infiltration ratio; W_M is average water storage irrigation in drainage area; W is the actual soil water content; K_F is sensitivity coefficient of soil water stress to infiltration ratio; B_F is spatial distribution characteristic parameters of infiltration capacity. P_E is precipitation subtracting from evaporation at rainfall time.

Groundwater runoff R_R is what we called the sum of soil – layer flow and groundwater runoff. It is calculated with the scheme of Dunne flow model, and can be represented as follows:

$$a = W_M(B+1)\left[1 - \left(1 - \frac{W}{W_M}\right)^{\frac{1}{B-1}}\right] \tag{19}$$

$$\begin{cases} R_R = F_A + W - W_M & F_A + a \geqslant W_M(B-1) \\ R_A = F_A + W - W_M + W_M\left[1 - \dfrac{F_A + a}{W_M(B-1)}\right]^{B+1} & F_A + a \pi W_M(B+1) \end{cases} \tag{20}$$

According to above theory, land – surface runoff, soil – layer flow and groundwater runoff can be calculated, and the storage water at different layers can be obtained at the same time.

5 Discussions

Irrigation requirement estimation is the key of water regulation in the Yellow River. We suggest that soil moisture monitoring model should be developed. With the model, soil moisture status can be estimated quickly with remote sensing technology in the irrigated area. At the same time, irrigation requirement analysis system should be opened to analyze water requirement one by one period of time at each irrigated area, and consequently realizing water fine regulation in the Yellow River.

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Study on Necessity of the West Route of the South – to – North Water Transfer Project from the View of Ningmeng Section

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Abstract: Located in the lower part in the upstream of the Yellow River, Ningmeng Section is the main water utilization area in the upstream of the Yellow River, the water distribution – index in normal year is 9. 86 billion m^3, and the current consumption has surpasses 10 billion m^3. Several prominent problems currently in Ningmeng Section are worsening sediment deposition of channel, severe situation of ice – jam control and flood control, and prominent contradiction between water resources supply and demand. The causes for the problems are improper water – sediment relationship and insufficient water resources. In the paper, the problems and the causes for problems are conducted, possible measures are briefed. It shows that the construction of Heishanxia Dam Project, the implementation of the West Route of the South to North Water Transfer Project as soon as possible to enlarge the Yellow River water resources quantity from headwater area are the important strategic countermeasures to solve the problems in Ningmeng Section.

Key words: Ningmeng Section, sediment deposition, ice – jam control, Heishanxia, the West Route of the South to North Water Transfer Project

1 Problems in Ningmeng Section and analysis on causes

1.1 Serious sediment deposition of channel

1.1.1 Water – sediment characteristic and sedimentation variation

Ningmeng Section has the features of different for water – sediment sources and concentration of water and sediment. The water mainly comes from upstream Jimai – Tangnaihai range and Xunhua – Lanzhou range, where over 20 tributaries join, e. g. , Taohe River, Datonghe River, Huangshui River, etc. , and the annual inflow takes over 60% of the runoff at Xiaheyan. The sediment mainly comes from the tributaries in Lanzhou – Xiaheyan section and other sections, e. g. , Qingshuihe River, Hongliuhe River and Kushuihe River, etc. in Ningxia, Xiliugou and other 10 large intermittence streams in Inner Mongolia.

Great changes have taken place on water – sediment characteristic in Ningmeng Section after the completion of Longyangxia and Liujiaxia reservoirs. From 1961 (the year when Yanguoxia was put into operation) to 1968, the river channel was balanced between deposition and scouring. After the operation of Liujiaxia Reservoir in 1968, the annual mean inflow and in – sediment at Xiaheyan Station from 1968 to 1986 are 31. 88 billion m^3 and 0. 107 billion t respectively, water volume in flood season is 16. 91 billion m^3 which is 53% of the total, the sediment volume in flood season is 0. 089 billion t which is 83. 2% of the total. The annual mean sediment deposition of Ningmeng Section in this duration is 0. 022,4 billion t, in which Xiaheyan – Qingtongxia range is slightly deposited, Qingtongxia – Shizuishan range is scoured, and the reason mainly is that the large amount of sediment is stored by Liujiaxia and Qingtongxia reservoirs and downstream scouring occurs when clear water is discharged. Inner Mongolia Section is deposited. Sediment from Maobulang intermittence stream and the 10 large intermittence streams joins in Zhaojunfen – Putanguai, resulting in a serious deposition. After operation of Longyangxia Reservoir, the operation changes the water – sediment condition and the character of river course souring, resulting in more serious deposition in main channel. The analysis shows that annual mean deposition in Ningmeng Section is 0. 083,6 billion t, mainly in Inner Mongolia Section. The annual mean deposition in Shizuishan –

Putanguai range in Inner Mongolia Section from 1993 to 2000 is 0.070,2 billion t, the annual mean deposition in Inner Mongolia Section from 2000 to 2004 is 0.056,7 billion t, resulting wide, shallow and disordered channel, more swinging and serious bank collapse.

1.1.2 Causes for channel deposition

The key cause for deposition worsening in Ningmeng Section is the change of water – sediment condition, featuring as the following three aspects:

The first is the decrease of upstream natural inflow. The statistics shows that the annual mean precipitation at Tangnaihai Gauge Station is about 480 mm, basically in a stable state. However, the change of underlying surface condition leads to the great change of river runoff. Based on the analysis, the annual mean runoff at Tangnaihai Station from 1950 to 2005 is 20 billion m^3, and the annual water volume after 1986 is 18 billion m^3 which is a reduction of 10%, i. e., 2 billion less than annual mean value.

The second is the great decrease of water volume coming to Ningmeng Section in flood season induced by the reservoir regulating of Longyangxia and Liujiaxia reservoirs and by industrial water increase. Under the natural condition (the series measured at Xiaheyan Station from November in 1950 to October in 1968 is taken as the representative), the annual mean water and sediment volumes in Ningmeng Section are 32.14 billion m^3 and 0.213 billion t respectively, the water volume takes 61% and the sediment takes 87.6% in flood season. The duration from November in 1968 to October in 1986 is the operation period of Liujiaxia Reservoir. In this period, the upstream reservoir stores sediment, so the in – sediment at Xiaheyan is 0.107 billion t which is 44.4% of the natural in – sediment, but the inflow rate decreases by 9.7% compared with the natural condition while the in – sediment decreases only by 6.8% in flood season. From 1986 to 1988, the water – sediment condition in flood season is further worsened, water volume takes only 42.1% and sediment takes 78.4% in flood season.

The third is the great decrease of large flow occurrences in Ningmeng Section since 1986 resulted from the great reduction of flood volume induced by the large storage volume in Liujiaxia and Longyangxia reservoirs in flood season. The statistics shows that days when flow in flood season at Xiaheyan is more than 2,500 m^3/s and 3,000 m^3/s decrease from 29.2% and 14.2% under the natural condition to 2.5% and 1.9% respectively after 1986, and the flow is less than 1,000 m^3/s in most of the other time. Under the condition where the tributaries, intermittence streams and aeolian sediment increases instead of decreasing in Ningmeng Section, the great decrease of large flow in flood season lowers the sediment transport capacity of the flow greatly, and the main channel sedimentation can not be flushed, resulting in the severe main channel deposition of the river.

1.2 Severe problems in ice – jam control and flood control

Coming out of Heishanxia, the Yellow River runs from southwest to northeast, the lower part has a higher temperature than the upper part, and consequently, the river in this section freezes from the lower part to the upper part and melts from the upper part to the lower part. In the freezing period, the lower part begins first and then the upper part follows, resulting in ice – jam dammed water, overflowing and inrush. In melting period, the upper part begins first, the channel water is released, but the lower part is still freezed, the flowing capacity under ice is not sufficient for the ice flood peak from the upper part, resulting in ice dam which endangers the bank and even produces disasters. After 1986, because of the server main channel deposition and worsened river course state, dammed water and ice berg disasters increase in freezing period, and 5 ice – jam inrushes occurred, this is the most frequent occurrence period of such incidents after 1949, and great dangers exist in each ice – jam period. For instances, the serious dammed water appeared in Bayangaole in the freezing period in 1988, resulting in over 0.1 million mu of farmland, pastureland and woods were inundated, over 40 villages were in the water. The ice – jam disasters after that, e. g., the disasters in 1990, 1993, 2001, etc., brought about great losses to the people along the

Yellow River.

The improper water – sediment relationship leads to the serious main channel deposition and decrease of channel discharging capacity in Ningmeng Section, the over – channel discharge decreases from about 2,500 m^3/s under the natural condition to 1,500 m^3/s (with the minimum at 1,000 m^3/s in some parts), being a great threat to the safety of flood control. In case of sediment – laden flood in tributaries, sedimentation occurrences in the Yellow River increases, leading to great losses. For instances, the year 1989 is a rich flow and lack sediment year, but the in – sediment of the 10 large intermittence streams produced barriers at the tributary mouths, sedimentation appeared in the Yellow River, resulting deposition of floodplain and main channel, and the dammed water in height of 2. 18 m at Zhaojunfen, which is a great threat to the safety of flood control.

1.3 Prominent contradiction between water resources supply and demand

Ningmeng area has scarce precipitation and poor local water resources, the development of agriculture irrigation and social and economic development rely on the Yellow River mostly. In accordance with the Allocation Scheme for Yellow River Available Water Resources (GUOFABAN, 1987 No. 61) approved by the State Council, the allocated consumed the Yellow River water volume index for Ningxia and Inner Mongolia is 9. 86 billion m^3 before the operation of the South to North Water Transfer Project. The statistics shows that the intake (consumed) water volume by irrigation areas in Ningmeng Section increases with year gradually, it increases from 8 billion m^3 in 1970s to over 10 billion m^3 at present, the water utilization is concentrated in the period from May to July which is 65.4% of the used water in the whole year, resulting in decrease of channel runoff in flood season, more improper water – sediment relationship and more channel deposition.

Being the important energy and heavy chemical industry base of China, Ningmeng area has rich coal resources. With the implementation of West Development Strategy, the industry areas and cities in the west part of Ningxia and Inner Mongolia will develop fast, and the rapid increase of water demand will lead to a more prominent contradiction between water resources supply and demand.

1.4 Knowledge on the existing problems

Because of the insufficient water resources, the contradiction between water resources supply and demand is getting more and more serions, large amount of water for eco – environment is used up by national economy, an improper water – sediment relationship appears. This does not only lead to the severe main channel deposition and shrinkage, decrease of flood discharging capacity of main channel, worsening of river course state, serious ice – jam control and flood control condition in Ningmeng Section, but also lead to sever main channel deposition, worsening of river course state and more burden for ice – jam control and flood control in the downstream of the Yellow River and in Xiaobeiganliu Reach. Therefore, in order to solve the current and future problems in Ningmeng Section, water saving must be greatly promoted, interbasin water transfers shall be implemented to increase the Yellow River water resources, guarantee eco – environmental water inside channel, and harmonize the water – sediment relationship.

2 Eco – environmental water demand in Ningmeng Section

The inside – channel eco – environmental water index refers to the water volume which shall be reserved inside channel to keep a certain state and a certain function of river. As for Ningmeng Section, it can be generalized as water volume for sediment transport in flood season and eco – environmental base flow in non – flood season.

2.1 Water volume for sediment transport in flood season

2.1.1 At Toudaoguai Section

The sediment transport in Ningmeng Section is mainly in flood season. Based on the flushing quantity calculation result in sediment quantity balance method, the annual mean deposition in Ningmeng Section is 0.051,3 billion t, deposition and scouring in Ningxia Section are almost balanced, annual mean deposition is 3.4 million t, taking 6.6% of the total deposition. Deposition is mainly concentrated in Inner Mongolia Section, in which deposition in Bayangaole – Toudaoguai range is serious, taking 86% of the total deposition in Ningmeng Section. Therefore, only the water volume for sediment transport in Bayangaole – Toudaoguai range is analyzed.

The analysis shows that in Bayangaole – Toudaoguai range in the duration from November in 1961 to October in 1986, the annual mean deposition is 8.8 million t in the thickness of 0.07 ~ 0.014 m, while in the duration from November in 1986 to October in 2004, the annual mean deposition is 68 million t in the thickness of 0.058 m. In order to recover and maintain the flood discharging capacity of the main channel in Ningmeng Section, the annual mean deposition thickness shall be controlled as about 0.01 m, and then the annual mean deposition shall be controlled as about 12 million t.

On the basis of measured data in the duration from November in 1966 to October in 2004 and with the consideration of inflow and in – sediment from tributaries and of water and sediment intake in the river section, the relationship between the water volume for sediment discharge and channel molding and the inflow and in – sediment at Toudaoguai is established as follows:

$$W_{flood} = \kappa_1 W_{sflood} + \kappa_2 \Delta W_{sflood} + c$$

in which, W_{flood} is the water volume for sediment transport and channel molding in flood season at Toudaoguai, in unit of 10^8 m^3; W_{sflood} is the flushing quantity in flood season from Bayangaole to Toudaoguai, in unit of 10^8 t; κ_1 and κ_2 are the coefficients respectively; c is the constant.

It is predicted that the future annual sediment volume at Bayangaole will be 0.091 billion t, including 0.066 billion t in flood season; the in – sediment in flood season in Bayangaole – Toudaoguai range will be 0.031,2 billion t. In flood season, with the allowable channel deposition being 0.012 billion t, the water for sediment transport and channel molding shall be 12.7 billion m^3.

2.1.2 Water demand for sediment transport and channel molding at Toudaoguai required by Xiaobeiganliu sediment transport

Based on the measured data statistics at Longmen Station and Hejin Station in the duration from July in 1950 to June in 2003, the annual mean water and sediment are 28.29 billion m^3 and 0.816 billion t respectively. The inflow and in – sediment in Xiaobeiganliu Section decreases from 1986 to 2004, the distribution proportion in year changes and the annual mean inflow and in – sediment are 19.79 billion m^3 and 0.45 billion t respectively. In Xiaobeiganliu Section, the annual mean deposition is about 0.1 billion t under natural state and the annual mean deposition is 0.054 billion t from 1986 to 2003. With less occurrences of large flow in the recent years, sediment deposits on the main channel basically and flood discharging capacity is lowered. In order to recover the flood discharging capacity of the main channel, the deposition on the main channel shall be lowered, and the proper annual deposition level is ascertained as 20 million t after the comprehensive analysis.

The relationship between scour with section method from 1974 to 2004 and flood – season unit sediment – transport water is set, shown as follows:

$$W_{Long+Heflood} = W_{sflood}\left(\frac{c}{\Delta W_s}\right)^{\alpha}$$

in which, $W_{Long+Heflood}$ is the water volume for sediment transport in flood at Longmen and Hejin, in unit of 10^8 m^3; W_{sflood} is the in – sediment in flood season in Xiaobeiganliu, in unit of 10^8 t; ΔW_s is the deposition volume of the corresponding deposition level in Xiaobeiganliu, in unit of 10^8 t; c is a constant; and α is an index.

At the level of 2030, the annual mean sediment in flood season at Longmen Section will be 0.511 billion t, in order to keep a deposition of 0.08 billion t in flood season in Xiaobeiganliu, under the condition of the annual mean deposition of 0.02 billion t, the water volume for sediment transport in flood season at Longmen Section shall be about 14.7 billion m^3. The statistics of measured annual mean data shows that the inflow volume in flood season in Hejin – Longmen range is about 1.9 billion m^3, after deducting the inflow in Hejin – Longmen range, the discharge water at Toudaoguai Section in flood season is 12.8 billion m^3.

As a summary of the above, the water volume for sediment transport and channel molding at Toudaoguai Section shall be 12 billion m^3 through calculating water volume for sediment transport on the basis of Ningmeng Section itself and through calculating water volume for sediment transport at Toudaoguai Section on the basis of Longmen Section in Xiaobeiganliu.

2.2 Eco – environmental base flow in non – flood season

Based on the result of study on environmental water inside the Yellow River channel completed by Department of International Cooperation Science and Technology, YRCC, and with the consideration of water volume for no zero – flow in river course and for water body self – cleaning, etc., the environmental flow in non – flood season at Toudaoguai Section shall not be less than 250 m^3/s, and the eco – environmental water volume inside channel in non – flood season at Toudaoguai Section shall be 5.2 billion m^3; the analysis with the consideration of the importance of ice – jam control in non – flood season in Ningmeng Section shows that the water demand is 5.7 billion m^3 from November to March and 2 billion m^3 from April to June, so the eco – environmental water volume from November to June shall be 7.7 billion m^3. Therefore, the eco – environmental water volume in non – flood season at Toudaoguai Section is 7.7 billion m^3 under the condition of satisfying the requirements for ice – jam control and for eco – environment.

As a summary of the above, the eco – environmental water inside channel in Ningmeng Section shall not be less than 20 billion m^3, in which water for sediment transport in flood season shall be about 12 billion m^3 and water for eco – environment in non – flood season shall be about 8 billion m^3.

3 Countermeasures and measures

3.1 Construction of water – saving society

Ningmeng area is in the typical arid and semi – arid zone with great shortage of water resources. Afpoesent, the water consumed and used by Ningxia and Inner Mongolia has surpassed the allocated index. With the progress of the West Development Strategy, industry and national economy will have a promotion, leading to more increase of water demand. Prior to the operation of South – to – North Water Tranfer Project, the primary measures are to construct water – saving society and to intensify water saving for the purpose of supporting the sustainable social and economical development in the basin with the limited Yellow River water resources. At present, water right transfer has been conducted gradually in Ningxia and Inner Mongolia, problem of part industrial water can be solved through saving agricultural water, the shortage of industrial water will be mitigated in a short time partly. But the water volume is too limited to solve the problems in long – term development.

3.2 The possibility of adjusting operation mode of Longyangxia and Liujiaxia Reservoirs to mitigate deposition in Ningmeng Section

Longyangxia Reservoir is the head reservoir in upstream of the Yellow River, and it can serve for multiple – year regulation. The joint operation of Longyangxia Reservoir and Liujiaxia Reservoir can perform multiple – year regulation for water volume, store the water in rich flow year to supplement the insufficiency in low flow year, store water in flood season to increase the flow in low flow season and to upgrade the output of cascade power station; meanwhile, control the discharge in ice – jam and flood seasons, reduce the burden of ice – jam in Ningmeng Section, and increase discharge at water use peak to raise guarantee rate of irrigation water supply.

The above analysis shows that the reason for deposition worsening in Ningmeng Section is the decrease of upstream inflow and increase of water use on one hand, and the decrease of flood season water volume percentage in the total year and the obvious decrease of large flow in flood peak period resulted from reservoir regulation which leads to the worsening of water – sediment relationship in Ningmeng Section on the other hand. Therefore, in order to lessen the deposition in Ningmeng Section, at first, water volume shall be sufficient, percentage of water volume in flood season shall be larger, and certain flood peak duration with large flow shall be required. So, under the possible condition, the operation mode of Longyangxia and Liujiaxia reservoirs shall be adjusted to obtain a relatively reasonable water – sediment process and to lessen the deposition in Ningmeng Section.

According to the design, besides the power generation task of Longyangxia and Liujiaxia cascade power stations, Liujiaxia Reservoir serves for the ice – jam control in Ningmeng Section. Under the precondition of satisfying requirement for ice – jam control and the minimum flow requirement for Hekouzhen, the regulation calculation based on design operation mode of Longyangxia and Liujiaxia reservoirs (the 79 – year series from July in 1919 to June in 1998) shows that the natural annual mean runoff in Hekouzhen is 32.3 billion m^3, and after deducting the above said water use of 12.7 billion m^3, the annual mean discharge water at Hekouzhen is 19.5 billion m^3, including 10 billion m^3 in non – flood season and only 9.5 billion m^3 in flood.

According to the above mentioned analysis on eco – environmental water volume in Ningmeng Section, in order to meet the requirement for the discharge of 12 billion m^3 at Hekouzhen, the operation mode of Longyangxia and Liujiaxia reservoirs shall be adjusted to increase flood season discharge about 2.5 billion m^3. Limited by the total water volume, increase water volume in flood season will surely lead to the water volume decrease in non – flood season. As a result, at first, unfavorable impact will be produced to the safety of ice – jam control in Ningmeng Section, secondly, water supply volume and guarantee rate in Ningmeng Section will be impacted, and thirdly, decrease of discharge water volume in non – flood season will bring great impact on the guaranteed output of cascade power station, the increase of discharge volume in flood season and discharging in large flow process will lead to large amount of surplus water which can not be used for power generation, and this will impact the power generation benefit of the cascade power station. The preliminary calculation shows that the annual mean power generation will be reduced by 9.284 billion kW · h and guaranteed output will be reduced by 1,499 MW.

With the implementation of the West Development Strategy, the water demand in Ningmeng Section will certainly have a rise, and the water insufficiency will be more serious, especially in non – flood season. In a certain period in the future, the state of suspended river will still exist and the problems in the ice – jam will be severe. Meanwhile, the decrease of guarantee output and power generation of Longyangxia, Liujiaxia and other power stations resulted from the adjustment of operation mode will cover the power demand from national economy and the safety of northwest power net system operation, etc. Therefore, with the consideration of the water demand from economic social development on both sides of Ningmeng Section, safety of river course ice – jam control, power system operation, sediment transport and deposition reduction in river course, etc., the total of upstream inflow shall be increased to create a harmonious water – sediment relationship with the combination of reservoir regulation, the deposition in Ningmeng Section can be mitigated effectively and the water for national economy can be ensured in this way, leading to a good function of Longyangxia and Liujiaxia reservoirs. Under the condition of no increase of the upstream inflow, lowering the deposition in Ningmeng Section only on the basis of adjusting the operation mode of Longyangxia and Liujiaxia reservoirs not only involves widely but also costs a lot.

3.3 Speeding up the construction of Heishanxia Dam Project

Located in the area connecting the upper part and the lower part, Heishanxia Section is the last river section in the upstream of the Yellow River where high dam and large reservoir can be built. The development of this river section must obey the general requirement for the Yellow River treatment and development, and must focus on solving the problems in ice – jam control in Ningmeng Section which is a primary task, on creating harmonious Yellow River water – sediment relationship, and improving river course state. Analyzed from the comprehensive treatment of Ningmeng Section, the completion of Longyangxia and Liujiaxia reservoirs has raised the guarantee rate of agricultural water in the river section and supported the economic and social development greatly. Liujiaxia Reservoir has played important role in ice – jam control in Ningmeng Section, but because of the long distance between the reservoir and Inner Mongolia section, the small reservoir storage, the inflexible dispatch, the large contradiction between ice – jam control dispatch and power generation, and the worsening of river section state, etc., the problem of ice – jam control has become the problem which is the most urgent one to be settled in the comprehensive treatment in Ningmeng Section in the future.

Under the condition of satisfying the requirement for harmonizing the water – sediment relationship in Ningmeng Section, for joint water and sediment regulation together with the key projects in the middle reach and for ice – jam control in Ningmeng Section, Heishanxia Reservoir serves for the regulation of the runoff process of the Yellow River upstream cascade power generation, satisfies the living, industrial and agricultural water demand in Ningmeng Section, makes benefit from water supply for industry and agriculture. Meanwhile, since the water supply from the reservoir can promote the development of ecologic irrigation area, improve the drinking water quality and living environment of the local people, and decrease the overburden of environment bearing capacity, it can play an important part in recovering the regional eco – environment.

Withont doubt, the implementation of Heishanxia Dam Project will certainly improve the water – sediment relationship in Ningmeng Section and even in the whole Yellow River, and will provide powerful support for ice – jam control, flood control, as well as provide water for national economy, etc. However, because of the contradiction between water for eco – environment (e. g., water for sediment transport inside channel, etc.) and the water for national economy, in order to make full use of Heishanxia Reservoir, the Yellow River water resources shall be increased from the headwater area through the West Route of the South to North Water Transfer Project, and the contradiction between water for sediment transport in flood season and the water for national economy in non – flood season can be further smoothed through regulation by reservoirs.

3.4 Speeding up the west route of the south to north water transfer project

The Yellow River has a water shortage in resources, the water utilization in the basin has surpassed the bearing capacity of the water resources, and diverting water from other basin is the strategic measure for the contradiction of water resources shortage. The water transferred to the Yellow River through the West Route of the South to North Water Transfer Project features as flowing from the high elevation to the low elevation, the position where the water enters the Yellow River is at high elevation with a full coverage of the areas which are short of water in upper, middle and lower reaches. The transferred water enters the water – sediment control system which consists of the large and medium scaled reservoirs on the Yellow River stem. Through large scaled regulating capacity, the uniform dispatch of the diverted water and the Yellow River water resources can be realized to harmonize the inconsistency between the Yellow River inflow process and the process of water into the Yellow River through the West Line and water for economic and social development and the process of water for channel sediment transport. Comprehensive consideration of water demand both inside channel and outside channel can lead to the optimized allocation of water resources, the full use of the diverted water, and the realization of the requirement for various river sections, various functions and various durations. The water volume allocated to the area outside channel flows through the main cities, large and medium irrigation areas, weak eco – environment zones, rich energy concentration areas in the basin, and hydro – power bases on the Yellow River stem, it can guarantee the water resources supply for economic and social development in the Yellow River basin and the related areas, lessen the contradiction between the Yellow River water resources supply and demand. Allocating water to the area outside channel can be conducted together with the storage of the key reservoirs, e. g. , Longyangxia, Liujiaxia, Heishanxia, Wangjiazhai, Qikou, Sanmenxia, Xiaolangdi, etc. , so as to guarantee no zero – flow in the Yellow River stem channel in low flow year, create harmonious water – sediment relationship, and improving the basic functions of river course in Ningmeng Section, Yutan Section and the Yellow River downstream.

4 Conclusions

In Ningmeng Section, there exist more deposition, severe ice – jam control and flood control problems, and prominent contradiction between water resources supply and demand. From the view of maintaining the basic function of Ningmeng Section and satisfying the requirement for the development of national economy, the implementation of the West Line of South – to – North Water Tranfer Project to increase the Yellow River water resources, and to create harmonious water – sediment relationship together with the regulation of Heishanxia and other reservoirs on the steam, and to promote the sustainable development of water resources, economy and society.

Ecological Effect Evaluation of Water Supply to Heishan Gorge Ecological Improvement Area of Ningxia by West Route South – to – North Water Transfer Project

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Abstract: With application of the principle of economics, we study the theory of consumer surplus by eco – environment improvement. According to the types and trait of ecological effect in Heishan Gorge Ecological Improvement Area, integrating with research results in China and overseas, we bring forward the calculation method for ecological effect evaluation. On the basis of field survey, we set up the correlation parameters of effect evaluation, study the direct and indirect effect of all eco – environment improvement items, and calculate the total value of ecological effect.
Key words: Heishan Gorge Ecological Improvement Area, consumer surplus, ecological effect, utility, evaluation

Heishan Gorge ecological Improvement Area has a total land area of 11,819 km^2, surface water resources per capita and average cultivated land per capita are only 1/4 and 1/6 respectively of the averages of the Yellow River Basin, being one of the most water – shortage area in the basin, and main natural harms are aridity, wind and sandstorm, fluorosis and, water and soil erosion. If the first phase west route South – to – North water transfer project supplements water of 300 million m^3 to the Heishan Gorge Ecological Improvement Area (Ecological Area) of Ningxia, sandy land of 3,084 km^2 would be improved, farmland of 133,300 hm^2 effectively protected, and by means of these projects, such as building grassland fences, wind and sand protection forests, ecological economic forests and sand – protection medical herbs, farmers' income would be increased, resulting in obvious ecological and economic effect.

1 Economic principle of ecological effect

A basic principle of welfare economics states: all costs are displayed by reduction of people's welfare utility, and income is finally presented by increase of welfare utility. Ecological value is reflected by products directly supplied and ecological service function indirectly supplied, including improvement of ecological factors affects production functions, progress of environmental quality improves service functions, all being displayed by the change of welfare.

define Western economics the product demand for maximization of consumer's utility as Marshall Demand, expressed with $x(P,M)$:

Target of utility maximization: $\mathrm{Max}U(x)$;

Constraint condition:

$$p_1x_1 + \sum_{i\neq 1} P_ix_i \leqslant M \tag{1}$$

where, $U(x)$ is consumer utility coefficient, P is price vector, M is budget expenditure. And the minimum expenditure under the level of given utility is defined as Hicksian demand, expressed with $x^h = (x^h(P,U))$:

Target of utility minimization: $e = \min p_1x_1 + \sum_{i\neq 1} p_ix_i$

Constraint condition:

$$u(x) \geqslant U \tag{2}$$

where, e is consumer expenditure function, U is consumer utility level to be obtained.

The value for the change of ecological conditions is displayed by the change of offered service and quantity of products and consumer surplus in the form of compensation surplus (By keeping the initial utility level and maintaining the indifference curve u_0, consumer obtains surplus), that is the area below consumption curve and above demand curve. On the condition maximization of consumer's utility, Hicksian demand gets the same surplus as Marshall Demand.

$$CS = -\iint x(P,M)\,\mathrm{d}p\mathrm{d}r = -\iint x^h(P,U)\,\mathrm{d}p\mathrm{d}r \quad (3)$$

Based on Shephard's lemma: $x^h(P,U) = \partial e(P,U)/\partial p$, consumer surplus is expressed by:

$$CS = \iint \partial e(P,U)/\partial p\mathrm{d}p\mathrm{d}r = e(P,r^0,u^0) - e(P^1,r^1,u^0) \quad (4)$$

where, CS is consumer surplus, $e(P,r^0,u^0)$ is minimum expenditure for obtaining u^0 at the original quantity and price level.

The calculation for consumer surplus CS is carried out to estimate the value of ecological service and products offered by eco – environment.

2 Measurement of ecological value

There is no an easy way to directly measure consumer surplus. Mithell and Carson[1] carried out a lot of studies and classification for evaluation: the first class refers to the value of direct monetization, which is evaluated by the direct market; the second class refers to indirect deduction of the value of money on the basis of selected models.

2.1 Evaluation by direct market

2.1.1 Output value method

The eco – system is taken as an element in production, and its change will lead to differing of productivity and production costs, and further affect prices and output level, or lead to loss of production or predicted effect. For example, air pollution results in decrease of crop production, affecting prices of agricultural products. Ecological products are valued as:

$$V = P_1Q_1 - P_0Q_0 \quad (5)$$

where, V is value of ecological product; P_0 is original price vector of product, P_1 is price vector of product changed.

2.1.2 Opportunity cost method

Resources always have traits of scarce and multiple uses. One choice means to give up other opportunities, and also lose corresponding income. Maximum economic effect of other options is taken as opportunity cost of the choice. For example, the eco – system of a wetland is developed to be farmland, and its opportunity cost is the sum of all kinds of effect available when the wetland is at the original state. The method is expressed by:

$$C_k = \max(E_1, E_2, \cdots, E_n) \quad (6)$$

where, C_k is opportunity cost of option k, $E_1, E_2, \cdots, E_n$ are effect of the options mutually exclusive with k.

2.1.3 Human capital method

Market price and salary determine personal potential contribution to society, by which loss is estimated for the change of eco – environment affecting human health. Usually the loss is equally estimated by using personal working value.

2.2 Indirectly computed value

2.2.1 Protection expenditure method

This method is to conclude people's estimation to the environmental value according to expenses to be used for prevention of environmental degradation. The method effectively exposes people's willingness to pay for air, water quality, noise and land degradation, fertility loss, soil erosion and pollution.

2.2.2 Condition value method

Condition value method is to understand their willingness to pay through direct survey on consumers. The key of the method is to investigate people's willingness to pay for ecosystem services, to express the economic value of ecosystem by willingness to pay.

2.2.3 Land value method

Land value method is used to estimate the loss of cultivated land and forest resources due to secondary and tertiary industries. Land is a kind of resource for sustainable utilization and considered comprehensively from recovery fund, land compensation and land occupation tax.

2.2.4 Substitute market value method

The change of eco – environment quality does not lead to the change of commodity and working output, but may affect the market price of other commodity substitutes or supplements and labor. Market information can be used to indirectly estimate the value of changed eco – environment quality. The method is used for estimating the loss of nutrients due to soil and water loss, and the loss of oxygen releasing capacity due to forest destruction.

2.2.5 Shadow engineering method

Shadow engineering method is also called substitution engineering method. It is usually adopted when it is difficult to directly estimate economic value of environment, and similar substitution engineering works can be used to express the value of the eco – environment. For example, estimation of the values of organism produced by forests, water sources nurturing and sediment loss prevention is expressed by:

$$V = f(x_1, x_2, \cdots, x_n) \tag{7}$$

where, V is value of eco – environment to be derived; $x_1, x_2, \cdots, x_n$ are construction expenses of all items with substitution works.

3 Evaluation of ecological effect

In accordance with the landscape ecology method, Heishan Gorge Ecological Improvement Area is divided into four types of eco – environment: forest, grassland, agriculture and resettlement for respective effect evaluation.

3.1 Forest ecological water effect analysis

3.1.1 Forest – nurtured water source effect

Nurturing of water sources is one of the important ecological functions of forests with respect to precipitation interception, trans – evaporation, intensifying of infiltration in soil, restricting of evaporation and slowing down of surface runoff. The effect estimation is made by substitution engineering method, assuming a storage project being similar to forest – nurtured water volume, and the project value substitutes that of forest – nurtured water source. Precipitation storage by forests is expressed by:

$$Q_2 = J_1 R = J R_1 R \tag{8}$$

where, Q_2 is precipitation storage in forests, J_1 is precipitation in forests, J is total precipitation in forests, R is percentage of forest – nurtured water to precipitation in forests, R_1 is forest coverage.

In accordance with the planning for the target area, the Ecological Area has forest coverage of 38%, total water storage in forest soil of 61 million m^3. Based on the cost of reservoir storage of 3.87 yuan/m^3, and the stage – development coefficient of 0.21, the forest – nurtured water source has the benefit valued at 42 million yuan.

3.1.2 Soil conservation effect

Effect of soil conservation in forests includes three parts: one is reduction of top soil loss; the second is reduction of nutrient loss; the third is reduction of deposition loss. The first two parts are calculated by increase of farmland production as well as forest and side products, and the third part is obtained by the shadow engineering method.

(1) Effect of increased production of protection forests. The effect is expressed by increased production of crops being protected by forests in a growing period. This is included in agricultural ecological effect.

(2) Effect of forest and side product output. The effect includes three parts; one is timber, including output of all kinds of timber; the second is other side – products, i. e. branches and leaves used as fuel, fodder and fertilizer, called as "three materials"; the third is side and special products, i. e. medical herbs and economic forests.

As shown in Tables 1 and Table 2, in the Ecological Area, timber profit is 66 million yuan; forest and side product effect is 15 million yuan; "three materials" produce effect of 3 million yuan. As the Ecological Area is the land to be developed, the total output effect of economic fruits is included, being 136 million yuan; for forest and side products, the total effect is 220 million yuan.

Table 1 Output effect of timber, side – products, specialties and "three materials" in Ecological Area

Forest, side product	Timber	Side product, specialty	Three materials
Planting area($10^4 hm^2$)	2.05	0.31	2.26
Sale price[yuan/(hm^2 · a)]	78,000	27,600	495
Forest cost[yuan/(hm^2 · a)]	74,500	22,300	315
Chopping & transport cost[yuan/(hm^2 · a)]	260	300	55
Output effect(10^8 yuan)	0.66	0.15	0.03

Table 2 Economic fruit output effect of Ecological Area

Type	Medlar	Glucose	Herb	Date
Planting area($10^4 hm^2$)	0.15	0.11	0.25	0.09
Production(kg/hm^2)	3 000	22 500	1 800	10 500
Unit price(yuan/kg)	10.0	1.75	8.0	1.2
Increased production effect(10^8 yuan)	0.45	0.43	0.36	0.11

(3) Effect of sedimentation reduction. In accordance with sediment movement in the stem Yellow River and tributaries, 32% of soil erosion loss is found in reservoirs and river channels. Effect of sedimentation reduction E_s is calculated by sediment clearing:

$$E_s = 32\% \times A_c \times C \quad (9)$$

where: E_s is sedimentation reduction effect, C is sediment clearing effect, A_c is conserved soil.

In the Ecological Area, prior to soil and water conservation work, soil loss is 2,000 ~ 5,000 t/(km^2 · a), and based on the level of 35,00 t/(km^2 · a), conserved soil and water area is 206,000 hm^2, and based on reduction of soil loss of 50%, soil and water conservation is 3.600,5 million t. With sediment clearing cost of 6.13 yuan/ t in Ningxia – Inner Mongolia section, sedimentation reduction effect is 2 million yuan.

3.1.3 Air – cleaning environment effect

Functions of air – cleaning forests include: ① absorption of CO_2, yielding of O_2; ② absorption of SO_2, NH_3 and certain amount of Cu, Zn and other harmful gas and heavy metals; ③ absorption and restriction of dust and fog. Falling dust restriction rate of forest belts is 23% ~ 52%, and for drifting dust, the rate is 37% ~60%.

(1) CO_2 – holding effect. The calculation uses the formula:

$$V_c = \sum_{i=1}^{n} Q_i \times A_i \times S_i \times P_c \tag{10}$$

where, V_c is CO_2 – holding effect, Q_i is net yearly growth of forest type i in unit area; A_i is planting area of forest type i; S_i is CO_2 held by forest type i in unit volume; P_c is unit price for holding CO_2. The international common calculation uses the Swedish Charcoal Tax Method, and according to IPCC, carbon rate of temperate forests ($14.25/t C) is taken as carbon tax for CO_2, and as shown in Table 3, protection and economic forests are dominant in the Ecological Area, the effect of the protection forests holding CO_2 is 76 million yuan, and for economic forests 4 million yuan, and the total is 80 million yuan.

Table 3 Effect of forest holding CO_2 in Ecological Area

Tree type	Net yearly increase (m^3/hm^2)	Planting area ($10^4 hm^2$)	CO_2 hold (t/m^3)
Protection forest	100	1.83	0.365
Economic forest	45	0.25	0.298

(2) SO_2 – absorption effect. The calculation uses the following formula:

$$V_s = q \times A \times P \tag{11}$$

where, V_s is SO_2 – absorption effect; q is SO_2 – absorption average in study area; A is study area; P is investment cost for reduction of unit weight of SO_2.

(3) Dust – restricting effect. The calculation uses the following formula:

$$V_d = Q_d \times S \times C_d \tag{12}$$

where: V_d is dust – restricting effect; Q_d is dust – restricting capacity of forests, S is study area, C_d is dust – reducing cost.

As the study shows, SO_2 absorption capacity includes: for broad – leaf forests 88.65 kg/($hm^2 \cdot a$), for cunninghamia sinensis 117.6 kg/($hm^2 \cdot a$), for pine trees 117.6 kg/($hm^2 \cdot a$), averaged at 215.6 kg/($hm^2 \cdot a$); dust – restricting capacity: for spruce 32 t/($hm^2 \cdot a$), for pine trees 34.45 t/($hm^2 \cdot a$) and for broad – leaf forests 10.11 t/($hm^2 \cdot a$). The Ecological Area has a forest area of 20,600 hm^2, including economic trees mainly with dates, and protection trees mainly with fast – growing populus. Absorption of SO_2 is 1,828.23 t, investment cost of mandatory reducing SO_2 is 600 yuan/t, and SO_2 – absorption effect is 1 million yuan; dust absorption is 208,500 t, mandatory reduction cost is 170 yuan/t, and dust – reducing effect is 35 million yuan.

In the Ecological Area, air – cleaning effect of forests is 116 million yuan.

3.2 Grassland ecological water effect analysis

3.2.1 Husbandry effect

Economic effect of water supply to grassland is mainly from husbandry, including planting grass to raise goats and livestock. The effect refers to raising the small – tail coldness goat by the formula:

$$V_s = \frac{Q_g \times A_g}{q_a}(B_a - C_a) \tag{13}$$

where, V_s is husbandry effect; B_a is annual production value of every goat on an average; C_a is annual mean production cost of every goat; q_a is annual mean grass consumption of every goat; Q_g is annual mean grass production in unit area.

As materials show for the small – tail coldness goat, each goat has fresh fodder of 1,150 kg, and for big goats 0.2 kg daily; for a flock of 100 goats, production cost is 44,500 yuan, production value is 79,400 yuan, annual net effect is 34,900 yuan, and net average effect of every goat is 349 yuan. If manual grass production is 45 t/hm^2, net effect for raising goats on one hectare of grassland is 13,700 yuan/year, and economic effect of grass planting is 365 million yuan in the Ecological Area.

3.2.2 Ecological effect

It is mainly reflected in climate regulation, provision of biological habitat, and improvement of local environment quality. The total ecological effect is expressed by:

$$V = \sum_{i=1}^{n} \sum_{j=1}^{m} A_j P_{ij} \qquad (14)$$

where, V is total ecological effect of local grassland, P_{ij} is ecological effect in unit area of grassland, i is ecological effect of different kinds, and j is types of grassland.

As Xie Gaodi's study of the grassland ecosystem in Meng – Ning – Gan temperate semi – arid zone, ecological effect in unit area is 113.1 US dollar/($hm^2 \cdot a$), and with the rate of RMB yuan to US dollar of 7.98: 1.0, grassland ecological effect is 0.24×10^8 yuan/year in the Ecological Area.

Above all, total effect of grassland water supply is 389 million yuan.

3.3 Agricultural water supply effect analysis

3.3.1 Agricultural economic effect

Agricultural economic effect refers to agricultural products directly producing effect. The Ecological Area is nearly all undeveloped land, production effect increased by protection forests is completely the value of all crops planted.

Table 4 Direct effect of agricultural products in Ecological Area

Item	Corn	Wheat	Benne til	Vegetables	Subtotal
Plantation area ($10^4 hm^2$)	0.56	0.83	0.44	0.11	1.94
Production (kg/hm^2)	4,750	4,500	1,875	39,000	
Unit price (yuan/kg)	1.2	1.6	4.2	0.9	
Increased production effect (10^8 yuan)	0.32	0.60	0.35	0.39	1.66

3.3.2 Agricultural ecological effect

The effect mainly refers to soil conservation, water conservation, CO_2 holding, O_2 releasing, maintaining of nutrient cycling, and environment cleaning, expressed by:

$$V_s = E_s + E_w + E_a \qquad (15)$$

where, E_s is soil – conservation effect, E_w is water – conservation effect, E_a is air – cleaning effect, and soil conservation effect E_s expressed by:

$$E_s = E_{s1} + E_{s2} \qquad (16)$$

where, E_{s1} is soil – fertility conservation effect, E_{s2} is sedimentation reduction effect, and E_{s1} is expressed by:

$$E_{s1} = \sum_{i=1}^{n} A_c \times C_i \times P_i \qquad (17)$$

where, A_c is volume of soil conservation, C_i is net content of nitrogen, phosphor and potassium in soil, P_i is price of nitrogen, phosphor and potassium.

Base on present average price of fertilizer at 2,950 yuan/t in China, effect of soil fertility conservation is 120,700 yuan, as shown in Table 5.

Table 5 Effect of soil fertility conservation in Ecological Area

Item	Soil conservation (t/hm^2)	Nitrogen net content (t/t)	Phosphor net content (t/t)	Potassium net content (t/ t)	Farmland area ($10^4 hm^2$)	Soil – conservation effect (10^4 yuan)
Quantity	0.545	0.000,7	0.001,2	0.001,97	3.4	112.07

Sedimentation reduction effect E_{s2} is calculated using (10), and the value is 314,870 yuan.

Farmland – conserved water effect E_w is calculated using (9), and farmland cropping area is 34,000 hm^2 in Ecological Area, water conserved by farmland is 3,630.0 $m^3/(hm^2 \cdot a)$, and effect of water conservation by farmland is 39 million yuan. With farmland cropping area of 1.94×10^4 hm^2, net growth of farmland of 6.5 $t/(hm^2 \cdot a)$ and afforestation cost of 260.90 yuan/t C, air – cleaning effect of farmland E_a is 9 million yuan.

3.4 Analysis of water supply effect for ecological resettlement

In the Ecological Area, land extends widely and evenly, which is an ideal place for resettlement. With the west line south – to – north water diversion project in operation for water supply, man – made oases utilize land of 44,300 hm^2, and the irrigation area can hold 200,000 ecological relocatees. Farmland of 124,000 hm^2 is recovered for forests and grass growing in the southern mountainous area, trees and grass are planted at barren mounts for 120,000 hm^2.

From the view point of net growth of trees in irrigation areas being 10 to 20 times of that in non – irrigation areas, and with the previous calculation method for ecological effect of woodland, estimation is made by 6% of the effect in unit area of woodland, and the effect is 18 million yuan for ecological resettlement in woodland; grass production in irrigation areas is 20 to 30 times of that in non – irrigation areas, and with the previous method for irrigated grassland, husbandry effect in unit area can be calculated by 4% of that in irrigation areas, and the value is 126 million yuan. For biological habitats, effect in unit area is 113.1 US dollar/$(hm^2 \cdot a)$, ecological effect is 185 million yuan, and 313 million yuan for grassland in ecological resettlement area in southern mountains.

Water from the west line project can be supplied to ecological relocatees of 200,000 for drinking at Heishan Gorge. Water volume and quality are improved to reduce the loss due to illness, early death or disability caused by pollution. For reduction of relocatee laborer loss, based on calculation of laborers' ages of 20 to 50, disabled people due to illness caused by drinking of local water or long – term shortage of drinking water, or early death being 2% of total relocatee population on an average, and relocatees at the ages being 50% of the total, they are 100,000 persons, and 2,000 persons are disabled, and with annual labor loss per capita of 1,500 yuan, the total loss is about 3 million yuan. If health effect evaluation is made for sufferers of Kaschin – Beck disease, about 1,500 patients potentially with this disease, and annual health expense per capita is 800 yuan, reduction of the loss due to water supply for resettlement is 1.2 million yuan.

As shown in Tables 1 and Table 2, in the Ecological Area, timber profit is 66 million yuan; forest and side product effect is 15 million yuan; "three materials" produce effect of 3 million yuan. As the Ecological Area is the land to be developed, the total output effect of economic fruits is included, being 136 million yuan; for forest and side products, the total effect is 220 million yuan.

Above all, ecological effect of resettlement is 333 million yuan, including 329 million yuan for grassland and health effect of 4 million yuan.

4 Conclusions

On the basis of consumer surplus theory, we study methods for ecological effect estimation. With water supplementation of 300 million m^3 from the west route project to Heishan Gorge, effect analysis and calculation are made for the different ecological types of woodland, grassland, farmland and ecological resettlement area, and annual ecological effect from the water supply is 1.323 billion yuan, including indirect effect of 0.744 billion yuan, direct economic value of products of 0.585 billion yuan, and relocatee health effect of 4.2 million yuan. Ecological effect includes 358 million yuan for woodland, 24 million yuan for grassland, 49 million yuan for agriculture, 313 million yuan for resettlement. And economic value includes 220 million yuan and 365 million yuan for trees and grassland husbandry respectively.

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Sustainable Integrated Water Management DSS for East Route and Middle Route of South – to – North Water Diversion Project

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Abstract: As one of the four great projects of the 21st century, South – to – North Water Diversion Project will improve the water distribution pattern and relieve water crisis in North China, facilitate sustainable socio – economic1 development. Along with the development of economy and society, operation decision – making managementis significant in maintaining the sustainability of the large scale hydraulic works in terms of social, economic and environmental impacts. With the characteristic of the East Route and Middle Route analyzed, the sustainable integrated water management DSS is established , which will provide firm support on decision of sustainable social, economic and environmental development.

Key words: South – to – North water diversion, sustainable, water resources, integrated management, DSS

1 Introduction

The South – to – North water diversion project is the largest hydraulic project worldwide so far. It is designed and established to settle the water crisis of China and alleviate the water scarcity. This project will divert water 44.8 billion m^3 (1, 400 m^3/s) each year from the southern wet basin to the Yellow River basin and Hai River basin through three routes. The East Route (ER) will pump water 800 m^3/s from the Yangtze River to the city of Tianjin through 1,200 km. ER passes through areas suffering severe water shortage and pollution, and it will accelerate the sustainable development of these areas. The Middle Route (MR) will divert 13 billion m^3 of water annually from Taocha channel of the Danjiangkou Reservoir in the near future and afterwards it will divert water from the Middle Yangtze River according to the master plan. The water flows by gravity to Beijing and Tianjin through canals covering a total recipient area of 150 ,000 km^2. The first phase of MR project, which will divert 9 billion m^3 of water annually is ongoing and to be completed at about 2010.

Based on characteristics of ER and MR, the sustainable integrated water management DSS for them is developed. It can rationally allocate water resources through the macroscopic regulation and market mechanism to harmonize both the the water demands and demands between various regions and sectors, and the objectives, and maximize social, economict, and environment benefits, improve the operation management level of ER and MR first phse project, and become a valid support instrument for key decision makers.

2 ER DSS

2.1 Main problems

The diverted water from ER is mainly supplied for agriculture in northern Jiangsu province and for industrial and domestic users in Shandong province. It is not for agriculture in the Shangdong province or and other areas north of Yellow River due to high cost of long distance water transfer. For this reason the optimal allocation of water amongst different districts and sectors becomes an extremely complicated but important issue. Other problems are how to test the feasibility of the water allocation schemes, and how to implement them.

From the economic perspective viewpoint, local water resources are preferable to inter – basin diverted water for the cost of inter – basin diversion is much higher than local water exploitation. Diverted water can only be used in the dry season or for peak water demands. The need to strike the optimal balance between the exploitation of local water resources and the use of diverted water is the challenge with the ER project. In addition, implementation of a top – to – down management, which goes ,from long – term opertation plan (say, annual plan), to short – term and even real – time operation, is necessary for securing the success of the project. there was not a single intergrated DDS available despite the fact that many researches had been done.

The allocation model is intended to reach a reasonable balance between water utilizations of the diverted and the local water resources. The paper illustrates the methodology used in the development and utilization of the model aimed at the optimization of water resource management. The model constitutes a practical tool to support the operation and management of the ER's whole hydraulic system.

Water pollution is another aspect constituting a great challenge to the implementation of the ER operation. Water planned to be diverted is in fact taken from rivers and lakes characterized by booming irrigated catchments area and wide presence of industries, generally lacking of appropriate wastewater treatment. Chinese government put forward water pollution control and prevention measures to improve water quality in the ER area from year 2000. Nevertheless water quality aspects remain in need to be monitored in order to evaluate the effect of the major undertaken measures, consider the introduction of additional ones and generally analyze the impact of the ER on the environment.

2.2 General objective

The general objective of the ER DSS is to further develop the existing models of the ER and to deliver a DSS that will allow the integrated water resource management of the ER. The DSS will enhance the management of ER water resources and hydraulic facilities and it will become a valid support instrument for key decision makers wishing to readily verify the hydrological and hydraulic feasibility of specific socio – economic development strategies. Through the DSS, decisions of operation and management for the ER can be carried out based on hydrological and hydraulic analysis, scenario analysis of water allocation on different time and spatial scales, and water quality simulation in key areas.

2.3 Framework

Based on the database and models development, DSS interface will be designed as a package to integrate the models and interface for users' manipulation and data exchange. The DSS will define the regulation of water along the diversion and its distribution amongst sectors in all basins. The DSS is the core of models set, capable of verifying the hydrological, hydraulic and environmental feasibility of water allocation strategies.

Data collection and database establishment are the basis of the whole task, as they provide information for key issue study and models development and running. Key issue study gives out the conclusions from analysing the identified problems and provides of the basis for the models development. In the models development, each model interrelate other models(Fig. 1).

2.4 Model system

The long – term hydrological model presents input for yearly allocation model based on historical statistics and long – term weather forecast results. The yearly allocation model produces scenarios of water allocation among regions considering the "authorized proportion" principle. The

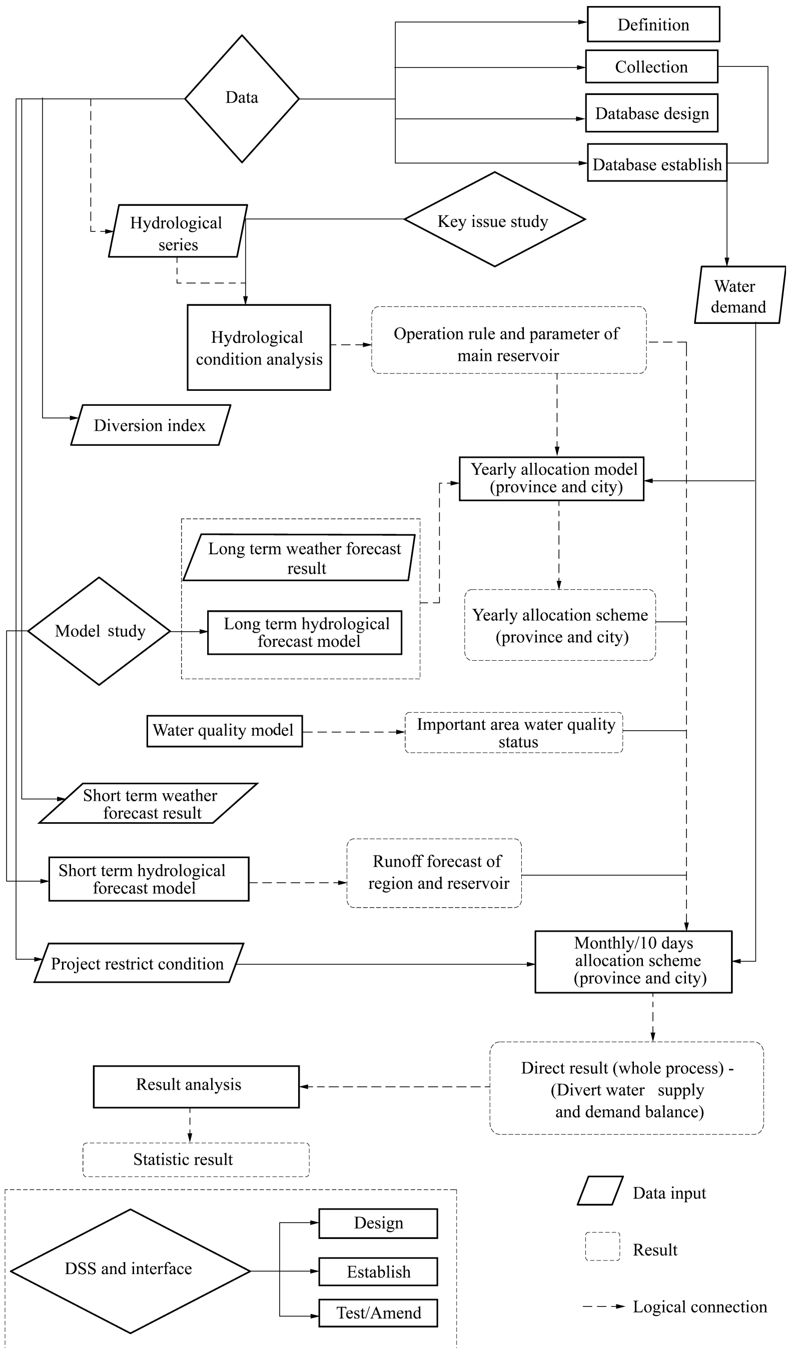


Fig. 1 Framework of DSS for ER

operational rules in different hydro – years provided by the key issue study will be applied in the development of the yearly operation model. The short – term water allocation model is developed based on the analysis of respective key issue study, while running of short – term allocation model takes results of long – term allocation model into account as constraints. Short – term hydrological model and water quality model will be developed independently. The output of short – term hydrological model will be used as input of short – term allocation model, while the output from short – term allocation model will provide information about discharge of sewage and reclamation for water quality model (Fig. 2).

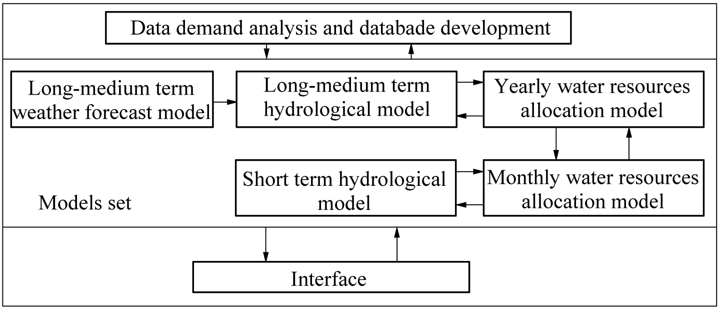


Fig. 2 Model system of DSS for ER

2.4.1 Long term hydrological model

The domain of the long – term hydrological forecast model is selected as to include most catchments area of Dongping, Nansi and Luoma Lake, i. e. water – receiving area of the ER. On the other hand, catchments area of Hongze Lake is not entirely in the domain of study area of ER, being largely located in upstream Henan, Hubei and Anhui province. Inflow data registered at a gauge station located downstream the Hongze Lake catchments area not included in the domain was set as the model boundary condition. The methodology of long – term hydrological model is regression analysis based on the historical data in monthly interval. Time Series Analysis Model and BP (Back – Propagation) ANN Model are applied for the long – term hydrological forecast.

The following three scenarios aimed at minimizing the forecast errors have been tested: ① Forecasted inflow: constitutes the main reference for the setting of operation scenarios; ② Maximum inflow: the flood control operations will be set down accordingly; ③ Minimum inflow: used to set down water supply crisis analyses.

Yearly and monthly runoff was forecasted for all sub – basins.

2.4.2 Short term hydrological model

The short term hydrological model is one component of DSS for ER, as illustrated in the above sections. It represents precipitation – runoff processes of watershed systems along the ER. The objective of the model is to calculate the available runoff for the short term water resources allocation model that will be used for the real time operation of the ER. HEC – HMS model is used as the tool for short – term hydrological forecast.

2.4.3 Long term allocation model

This part is to provide scenarios of annual water allocation based on monthly results. ROWAS developed by IWHR is applied as the tool in this part. ROWAS uses simulation to analyze water system and realize long – term water allocation within a framework, which describes the basic elements in water resources system and their mutual relations. In this framework, the complex process of water system could be described by adjustable relevant rules and respective parameters with experiences and pragmatic demands. The methodology of ROWAS is integrated by conceptual simulation and rule – based control. The rule set gives principles to design conceptual network of studied area and control the concrete processes of movement and conversion of different water flow, including water allocation among various areas and different water users.

2.4.4 Short term allocation model

The objective of short term allocation model is to seek monthly water allocation plan, i. e. 10 – day water resources allocation to different water user. The results of present monthly allocation from long – term allocation model are assumed to be the control condition in short – term allocation model. Generally short – term operation model is expected to provide guidelines on real – time decision regarding hydraulic facilities operations aimed at complying with water to be allocated to municipalities. The time step of calculation in short – term operation is fixed to be 10 – days.

2.4.5 Water quality model

This model is designed to estimate the hydraulics, convection and disperse of water when the river comes into lake taking contamination. Biology estate and estimate of pollution transform should be considered first of all, and then study on the interested side. As the above reasons, the model is a 2D model, and simulates convection and disperses of water not the hydrodynamic process.

3 DSS for MR

3.1 Differences between the operation of MR and ER

The distribution, water – receiving areas, and operational characteristic of MR and ER are different. That makes the ER DSS can not be replicated simply to MR. The difference involves 3 aspects.

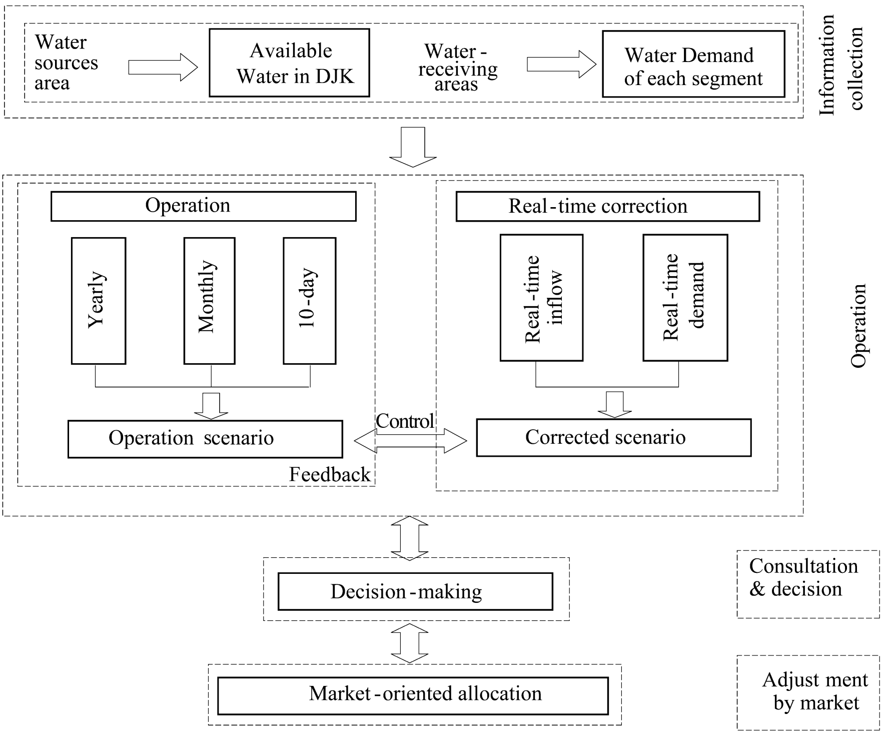
The quantity of diverted water from the MR is not only decided based upon the demand of water – receiving areas, but also influenced by the hydrological condition of Hanjiang River. On the other hand, the water diversion volume of ER mainly depends on demand of water – receiving areas and the physical capacity of hydraulic facilities, e. g. pumping stations. Therefore, there are more strict conditions for simulation of MR than ER. In ER, water pumped from Yangtze River passes through Hongze Lake, Luoma Lake, Nansi Lake, and Dongping Lake. The former three lakes are located in Huaihe river basin and the last one is in Shandong Province. Therefore, the ER is physically connected and mixed with the local water sources. Therefore the ER operations must consider the local water resources, including groundwater. On the other hand, MR project diverts water from Danjiangkou reservoir and there is no any direct hydraulic relation with local water system in the whole route. On the whole, the structure of MR system is much more complex than the ER. The management of the ER and of MR is dramatically different between them. For the ER, there are two water supply companies in charge of operation, in Shandong and Jiangsu provinces respectively. Those two companies are independent and politically equal each other and can carry out commercial activities for diverted water. Shandong Water Source Company can pay for water from Jiangsu Company when they need water, and Jiangsu Company can decide the available volume of water supply to Shandong based on the analysis of the hydrological condition and their own need. Basically, water quantity is not a problem for ER and the major limitations are water demand, physical capacity of facilities and economic cost for water transfer. Therefore, the two provinces can decide the operations of ER individually without central control.

3.2 General objective

The general objective of DSS for MR is to improve the technical level of operation of MR, and assist to realize rational water allocation through the macroscopic accommodation of government and market mechanism with consideration of water demand and hydrological condition in Danjiangkou reservoir and water receiving areas. Through reasonable decision – making, more social, economic and ecological benefit can be made from the great project.

3.3 Framework

The first step is to develop distributed hydrological model for catchments of Danjiangkou Reservoir and real – time self – adaptive operation model under multi – criterion control based on the database supporting the information of MR operation. Consequently, the integration of models for different functions can be realized to allow the information collection and supporting water resources operation, and the achievements from different models can be analyzed and displayed, implement the joint operation of local and diverted water. Finally, the general platform consist of the integrated models can be created make the reasonable scenarios for yearly and monthly water allocation of MR based on realistic demand of water diversion from water – receiving areas and platform of hydrological simulation in water source area(Fig. 3).



Remark: DJK is Danjiangkou reservoir

Fig. 3 Framework of DSS for MR

3.4 Model system

To ensure the validity, rationality and systematicness of water operation, the distributed hydrology model and multilayer multiuse real – time modification water operation model are created.

3.4.1 Runoff forecast model of Danjiangkou reservoir

Runoff forecast model of Danjiangkou reservoir is the important precondition of water operation, and its precision directly influence the effect of water operation. To ensure the validity, rationality and entirety of water operation, it should study the water circle simulation of core part of operation, confirm the runoff forecast model of Danjiangkou reservoir.

3.4.2 Water operation model of Danjiangkou reservoir

According the storage of reservoir at present, the runoff of reservoir in the future, water amount to be diverted from Danjiangkou reservoir at different period is decided by several factors, including the sluice demanded by the lower reaches of Yangtze River and water demand of the reception basin. And the operation should be complied with operation rules and other related guidelines.

3.4.3 Rationale of operation model for main trunk of MR

Based on the analysis of the objectives and limitations of MR, the rationale of MR operation can be concluded in one sentence: the basic requirements for MR operation model are "general control, combination of long – term and short – term operation, real – time decision – making, scrolling adjustment". "General control" means the long – term operation scenarios should be the base of practical fulfillment, to guarantee the reasonability of short – term regulation. "Combination of long – term and short – term operation" means the long – term water allocation scheme should be worked out based on long – term meteorological and hydrological forecast of water source area, then short – term operation scenario can be optimized with consideration of the limitation and range provided by long – term scenarios. "real – time decision – making" is to provide current operation decision with consideration of both hydrological and hydraulic situation,. "scrolling adjustment" means to modify the facing scenarios based on analysis of the gap between calculated scenario and the allocation carried out, which could make the future operation more reasonable and approach to real condition.

4 Conclusions

Along with the socio – economic development, the requirement of water management improved gradually. As the largest hydraulic project ever, South – to – North water diversion project will tardily settle the water crisis in China and alleviate the water demand at present and in the future. The study on water integrated management for this project is significant. The sustainable water integrated management DSS for them with consideration on management with social, economic and environment is put forward and implemented. It can support key decision for South – to – North water diversion water management and provide powerful guarantee for social, economic and environment. The results proved that more efforts are needed to put on construction of platform for integrated management in future.

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Optimal Allocation of Canal Water for Conjunctive Use Planning

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Abstract: OPTALL model based on quadratic programming technique was employed to minimize the gap between water supply and irrigation requirement and optimal as well as equitable water allocation plan to meet the irrigation requirement computed after considering average, 75% dependable and actual rainfall for various distributaries of Patna Main Canal under Sone Canal system in India was developed. The optimal water allocation schedule was found much better than actual release because in no case supply – demand ratio was more than 1. 0, whereas in case of actual release it was excessively higher than 1. 0 in many distributaries of Patna Main Canal showing inequitable water distribution. In order to utilize canal water equitably, efficiently and judiciously, canal operation schedules need to be developed and reviewed in consultation with water users under various situations of water availability. Through frequent meetings and dialogues between canal managers and water users and technical back stopping through such decision support tools, most of the water conflicts can be resolved. The gap between optimal water release and irrigation requirement indicates that there is a need to promote ground water utilization and explore the possibility of conjunctive use of rain, surface and ground water in canal command to minimize the gap and improve the yield.

Key words: Optimization, Canal water allocation, equitable water distribution, decision support system, conjunctive use

Water is one of the most important inputs for agricultural production. But due to wide variation in its spatial and temporal availability, it is not always possible to apply it to the crop when it is essentially required. Sometimes, in spite of sufficient water availability in the reservoir, water is not released, distributed and allocated timely, adequately and equitably among the farmers due to many technical, hydraulic, socio – economic, institutional, financial and managerial problems as mentioned by Upadhyaya (2002) and discussed in detail by Upadhyaya (2005). This leads to wide gap between water supply and water requirement in the canal command, resulting in either water logging or agricultural drought. Both the situations are detrimental and adversely affect the crop yield. This clearly indicates that there is sufficient scope to made water available to farmers in adequate quantity at right time, if canal managers properly plan, manage and release water as per crop water requirement. In this paper, optimal and equitable releases of water in the distributaries of Patna Main Canal under various scenarios of water availability by employing OPTALL model have been presented and gap between actual and optimal releases has been assessed for conjunctive use planning.

1 OPTALL model and its capabilities

In order to equitably allocate water among farmers, total water availability, water requirement and a mathematical model capable of optimally and equitably allocating water are required. There are a number of approaches to solve the optimization problem. These include dynamic programming, linear and non – linear programming. Of these, dynamic programming and non – linear programming (quadratic) have the potential to solve such problems in a better way because the optimization approach can offer significant benefits in terms of potential water saving, equity in water allocation subject to system constraints. OPTALL model developed at University of Edinburgh has the capability to allocate water optimally and equitably in various offtakes of Patna Main Canal keeping in view of the requirement and system constraints. Development of objective function in problem formulation is very important. Since the problem addressed was related to irrigation water management and in particular to ensuring optimal and equitable allocation of irrigation water for farmers, the most appropriate objective function as defined by Wardlaw and Barnes (1999) was as follows:

$$\text{Min} \quad Z = \sum_{i=1}^{n} \frac{(d_i - x_i)^2}{d_i}$$

where: n is the number of irrigation schemes, d_i the irrigation demand for scheme i, and x_i the irrigation supply to scheme i. The above equation is subject to canal capacity constraints, continuity constraints, and of course supply constraints.

OPTALL was used by Wardlaw and Barnes (1996) to model systems with complex distribution systems and has been demonstrated to be very robust. Wardlaw (1999) presented the optimization approach and procedure to solve real time optimization of water for better water allocation. Wardlaw and Bhaktikul (2001) applied a genetic algorithm (GA) to the water allocation problem as well, and while acceptable results were produced, they concluded that the GA offered no advantage over quadratic programming for this particular problem.

Data requirement of OPTALL model includes a schematic diagram of Patna Main Canal system network, which is first prepared manually and then with the help of software. Information about various reaches, irrigation schemes, nodes, branches, their capacity, seepage loss/gain and length is required to prepare the network input file.

Other input files need weekly water demand in m^3/s at all the nodes as defined in network file. Input file for weekly actual inflows diverted at the head of canal is also one of the input files.

With this input data OPTALL computes optimum and equitable release in the canal offtakes subject to system constraints. The optimal releases not only minimize the gap between water availability and water requirement but also give opportunity to equitable allocation and efficient utilizing the precious water in the command. This model is robust, relatively easy to apply, and has potential as a tool in decision support for real – time irrigation system operation. This approach can be used by scheme managers to improve the equity of water distribution under various scenarios of water availability.

2 Results and discussion

2.1 Actual and optimal canal water supply and comparison with irrigation requirement

Actual and optimal water releases in various distributaries of Patna Main Canal were studied and compared with irrigation requirement considering average, 75% dependable and actual rainfall of 2003 during Kharif (Monsoon) and Rabi (Winter) seasons in head, middle, tail and whole Patna Main Canal. Results are presented graphically for whole Patna Main canal in Fig. 1 ~ Fig. 4.

The Number of weeks having excess and deficit release in Patna Main Canal based on actual and optimal supply of canal water over irrigation requirement in head, middle and tail reaches as well as whole canal and range of variation have been summarized from graphs and are presented in Table 1 below. It may be observed from the figures that in case of actual water supply there is a wide gap between supply and irrigation requirement. In some weeks, supply is excessively higher than requirement, whereas in other weeks it is excessively lower than demand. Table 1 reveals that in case of actual release, during Kharif season the number of weeks having excess supply of canal water than irrigation requirement is less than the number of weeks having deficit supply of water, whereas during Rabi season trend is opposite and the number of weeks having excess supply are

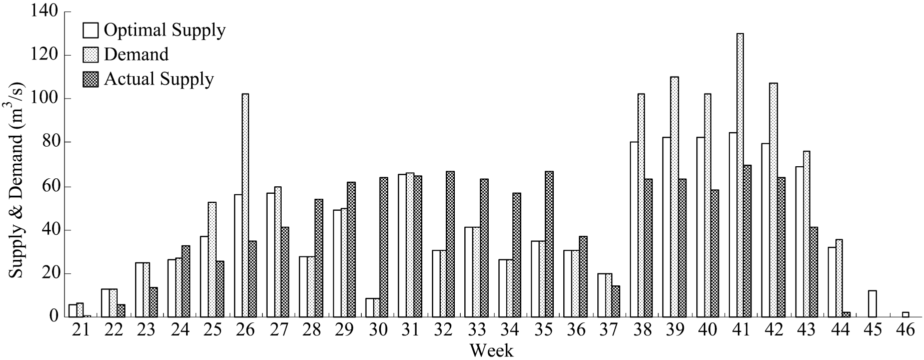

Fig. 1 Weekly optimal and actual supply as well as demand considering average rainfall in PMC

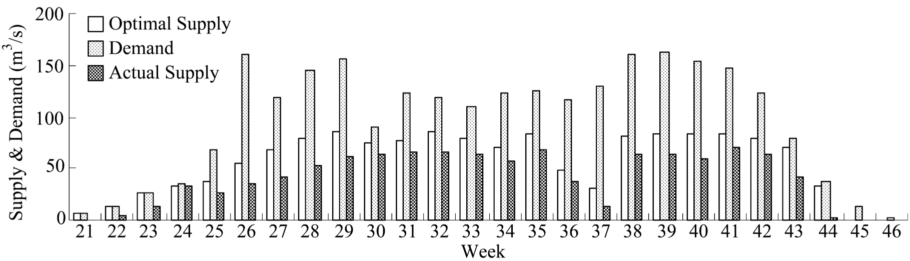

Fig. 2 Weekly optimal and actual supply as well as demand considering 75% dependable rainfall in PMC

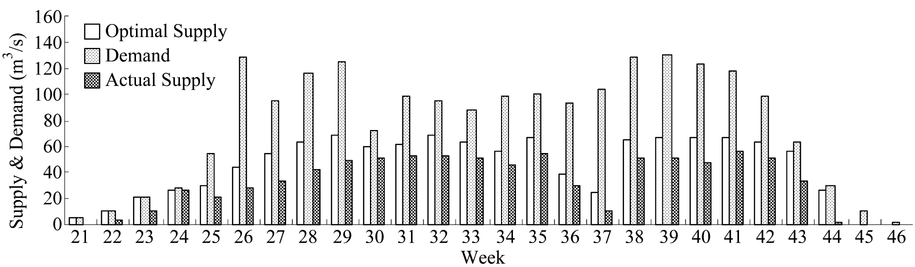

Fig. 3 Weekly optimal and actual supply as well as demand considering actual rainfall of 2003 in PMC

more than the number of weeks having deficit supply. The range of deficit supply is less than the range of excess supply, which indicates that there is scope to increase area under irrigation during Rabi period. In case of optimal release of canal water, none of the weeks have excess water supply and the number of weeks having deficit water supply is most of the time less than the case of actual release. The range of deficit water supply in case of optimal release is always less than the case of actual release. In Kharif season, deficit supply over irrigation requirement was highest for the case when irrigation requirement was computed considering 75 % dependable rainfall followed by the cases of actual and average rainfall. There is significant variation in excess and deficit supplies in head, middle and tail reaches as well. Results clearly indicate that optimal releases obtained after employing OPTALL model never show excess supply and the number of weeks having deficit supply

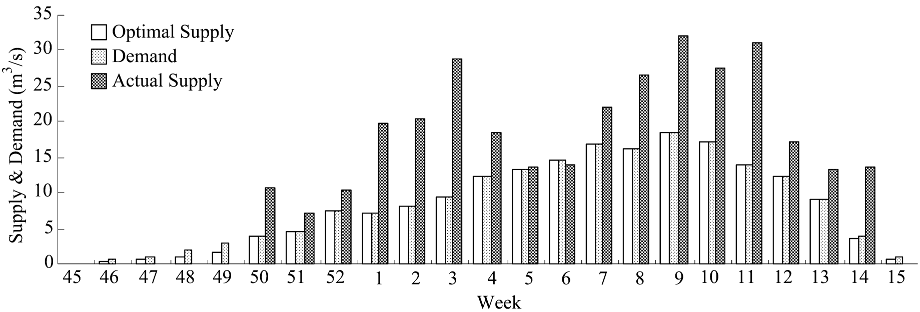

Fig. 4 Weekly optimal and actual supply as well as demand during Rabi season in PMC

as well as range of deficit supply reduce significantly and gap between supply and irrigation requirement minimizes in case of optimal release.

2.2 Actual and optimal supply – demand ratios in distributaries

Supply – demand ratios for all the distributaries of Patna Main Canal were computed for actual and optimal canal water supply as well as irrigation requirement considering average, 75% dependable and actual rainfall of 2003 during Kharif and Rabi seasons. Summary of distributaries with their supply – demand ratios in various weeks is presented in Table 2. It may be observed from this Table that in case of actual water supply, suqply – demand ratios excessively exceed 1.0 in many weeks in head, middle and tail reaches, whereas it is varying from 0.1 to less than 1.0 in other weeks. Only in very few weeks it is 1.0. On the other hand in case of optimal water supply, the supply – demand ratio never exceeds 1.0. It is 1.0 in many weeks. It is also less than 1.0 in the weeks when canal water is available in limited quantity. It is most of the time greater than 0.5 and equitable in all the distributaries subject to the system constraints. It shows that OPTALL model not only allocates water optimally but equitably as well, which may lead to efficient and effective utilization of canal water.

2.3 Gaps in optimal water supply and demand

Though, compared with actual water supply, optimal water supply could meet the demand equitably and optimally in many weeks during Kharif season and almost in all the weeks during Rabi season, yet during Kharif season in few weeks demand could not be met fully as shown in Fig. 2 ~ Fig. 5. In order to meet this gap there is a need to explore the possibility of ground water use and promote the concept of conjunctive use of rain, surface and ground water in the canal command to improve yields.

3 Conclusions

In order to minimize the gap between water supply and irrigation requirement OPTALL model based on quadratic, programming technique was employed and optimal as well as equitable water allocation plan to meet the irrigation requirement computed after considering average, 75% dependable and actual rainfall for various distributaries of Patna Main Canal under Sone Canal system was developed. The optimal water allocation schedule was found much better than actual release because in no case supply – demand ratio was more than 1.0, whereas in case of actual release it was excessively higher than 1.0 in many distributaries of Patna Main Canal showing inequitable water distribution. In order to utilize canal water equitably, efficiently and judiciously, canal operation schedules need to be developed and reviewed in consultation with water users under various situations of water availability. Through frequent meetings, interactions/dialogues between

Table 1 Number of weeks and range of variation in excess as well as deficit in release over irrigation requirement in Patna Main Canal

Reach	During Kharif considering average rainfall			During Kharif considering 75% dependable rainfall			During Kharif considering actual rainfall of 2003			During Rabi seson		
	Actual release		Optimal release	Actual release		Optimal release	Actual release		Optimal release	Actual release		Optimal release
	Excess over irrigation req. No. of weeks and Range (m^3/s)	Deficit over irrigation req. No. of weeks and Range (m^3/s)	Deficit over irrigation req. No. of weeks and Range (m^3/s)	Excess over irrigation req. No. of weeks and Range (m^3/s)	Deficit over irrigation req. No. of weeks and Range (m^3/s)	Deficit over irrigation req. No. of weeks and Range (m^3/s)	Excess over irrigation req. No. of weeks and Range (m^3/s)	Deficit over irrigation req. No. of weeks and Range (m^3/s)	Deficit over irrigation req. No. of weeks and Range (m^3/s)	Excess over irrigation req. No. of weeks and Range (m^3/s)	Deficit over irrigation req. No. of weeks and Range (m^3/s)	Deficit over irrigation req. No. of weeks and Range (m^3/s)
Head	11 (31.69 – 0.94)	15 (60.38 – 0.30)	10 (36.29 – 0.30)	1 (6.07)	25 (100.40 – 0.15)	22 (78.36 – 0.20)	13 (37.72 – 0.40)	13 (62.92 – 0.46)	10 (42.98 – 0.20)	15 (9.37 – 0.51)	5 (0.77 – 0.11)	6 (0.43 – 0.01)
Middle	9 (21.90 – 0.21)	17 (20.10 – 0.22)	13 (15.55 – 0.07)	—	26 (39.77 – 0.22)	23 (31.95 – 0.17)	7 (23.29 – 2.43)	19 (27.75 – 0.23)	16 (23.36 – 0.17)	15 (8.64 – 0.31)	7 (2.12 – 0.16)	6 (0.88 – 0.02)
Tail	11 (10.53 – 0.87)	13 (17.36 – 1.28)	14 (8.56 – 0.04)	5 (6.89 – 0.40)	19 (21.13 – 1.28)	23 (13.90 – 0.05)	7 (6.89 – 1.18)	17 25.07 – 0.67)	18 (16.32 – 0.05)	10 (4.24 – 0.38)	9 (0.80 – 0.02)	9 (0.04 – 0.01)
PMC	9 (55.70 – 5.86)	17 (67.33 – 1.13)	16 (46.25 – 0.15)	—	26 (125.80 – 1.13)	24 (104.73 – 0.37)	8 (56.37 – 1.26)	18 (86.07 – 1.13)	19 (68.92 – 0.37)	16 (19.24 – 0.48)	6 (2.98 – 0.16)	13 (1.35 – 0.01)

Table 2 Summary of distributaries partially or fully meeting out demands in various weeks and supply – demand ratios

Reach	Supply – Demand Ratio	During Kharif considering average rainfall				During Kharif considering 75% dependable rainfall				During Kharif considering actual rainfall of 2003				During Rabi seson			
		Actual Release		Optimal Release		Actual Release		Optimal Release		Actual Release		Optimal Release		Actual Release		Optimal Release	
		Weeks	No. of distrib – utaries (Range)	Weeks	No. of distrib – utaries (Range)	Weeks	No. of distrib – utaries (Range)	Weeks	No. of distrib – utaries (Range)	Weeks	No. of distrib – utaries (Range)	Weeks	No. of distrib – utaries (Range)	Weeks	No. of distrib – utaries (Range)	Weeks	No. of distrib – utaries (Range)
Head	>1.0	23	1 ~ 13	—	—	15	1 ~ 8	—	—	18	1 ~ 13	—	—	17	4 ~ 10	—	—
	1.0	9	1 ~ 2	16	13	6	1 ~ 2	5	13	4	1	8	13	7	1 ~ 2	20	3 ~ 13
	Partial	22	2 ~ 11	7	13	24	2 ~ 13	19	12 ~ 13	15	2 ~ 13	8	13	15	1 ~ 5	—	—
	0.0	5	1 ~ 9	1	13	8	1 ~ 9	—	—	6	1 ~ 9	8	13	21	1 ~ 13	8	1 ~ 13
Middle	>1.0	22	1 ~ 10	—	—	11	1 ~ 9	—	—	19	1 ~ 10	—	—	17	1 ~ 10	—	—
	1.0	7	1 ~ 2	13	10	6	1 ~ 2	3	10	4	1	13	1 ~ 10	2	1	20	4 ~ 10
	Partial	19	1 ~ 8	7	1 ~ 10	22	2 ~ 10	21	1 ~ 10	15	2 ~ 10	14	1 ~ 10	8	1 ~ 5	—	—
	0	7	1 ~ 10	—	—	7	2 ~ 10	—	—	8	1 ~ 10	6	1 ~ 10	20	1 ~ 10	7	2 ~ 6
Tail	>1.0	15	1 ~ 10	—	—	12	1 ~ 10	—	—	13	1 ~ 10	—	—	17	1 ~ 10	~	—
	1.0	4	1 ~ 2	7	10	4	1	2	2 ~ 3	4	1 ~ 2	9	2 ~ 10	4	1	19	3 ~ 10
	Partial	12	1 ~ 10	12	1 ~ 10	17	2 ~ 10	21	2 ~ 10	14	3 ~ 10	16	2 ~ 10	11	1 ~ 4	—	—
	0	7	1 ~ 10	8	1 ~ 10	6	1 ~ 10	6	1 ~ 10	5	7 ~ 10	6	1 ~ 10	16	1 ~ 10	15	1 ~ 10

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canal managers and water users and technical back stopping through such decision support tools, most of the water conflicts can be resolved. The gap between optimal water release and irrigation requirement indicates that there is a need to promote ground water utilization and explore the possibility of conjunctive use of rain, surface and ground water in canal command to minimize the gap and improve the yield.

Acknowledgements

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Site Specific Micro – Watershed Based Sustainable Hill Farming in Upper Catchments of Indian Himalya

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Abstract: The North West Himalaya is characterized by high altitude (1,000 m to > 3,500 m above msl), steep slope (15% to > 100% slope), high intensity rainfall (> 100 mm/h), prevalence of shallow and gravelly soil (7.5 ~ 15 cm depth and > 40 % gravel), severe degradation, loss of forest cover and inaccessibility (8.6 km length of roads compared to 37 km/100 km^2 in India). The region spreads over 33 million ha across Jammu and Kashmir, Himachal Pradesh and Uttarakhand states in India. Twenty two million people inhabit this region, who are supported by 2.14 million ha of cultivable land, with an average land holding of less than 0.1 hm^2. North – West Himalaya (NW Himalaya) mid – hills (600 ~ 1,800 m above msl), cultivation is mostly practiced on terrace hill slopes. Majority of the farmer's family produce only 4 ~ 5 months of sustenance food from its cultivated terraces (Ved Prakash and Narendra Kumar 2006). Thus, increase in the productivity of the micro watersheds has become the major thrust area for food security in the hills.

Shortages of land and low productivity are the cause for cultivation of steep and unstable hill slopes. Srivastava et al., (1983) reported that about 33 % of cultivated land belong to class Ⅴ, Ⅵ and Ⅶ against the norm of not cultivating any land having capability beyond Ⅵ yet farmers tends to cultivate steep slopes to increase production which leads to more erosion and loss of productivity. Agriculture in the region faces major problem of the water resources and its management as 90 % of the area is rainfed. The problem further gets aggravated due to slopy terrains and shallow soil depth, which allow major portion of the rain water to be lost as runoff (Singh et al, 2001).

Key words: water resources management, upper catchments of Indian himalya, micro – watershed sustainable, hill farming

1 Methodology

An exercise with benchmark participating farmers indicated their preference for appropriate, location specific farming risk minimization and efficient alternatives. Addressing these issues, 3 diverse agro – ecosystems based on aspect, slope and soil properties, which are dominant in mid – hills farming system were selected for the study. Response to variation in agro – ecosystem and growing conditions under selected farming system were observed. 5 cropping systems were chosen and were studied in the selected agro – ecosystems. The chosen crops were maize, okra, upland rice, finger millet and napier grass during kharif and wheat, lentil, pea, toria and hybrid napier during rabi season. The various parameters influencing the crop production such as soil physical condition, moisture regime, nutrient and extent of sunshine were observed. The runoff and soil loss during kharif were also recorded. The experimental area under various kharif crops are given in Table 1.

2 Results and discussions

Orientation of sites to sun resulted in marked variation in sunshine. The Attadhar site recorded 80% area under sun at 08:00 hrs. Correspondingly the sunshine at 08:00 hrs decreased to 68% area for Khakal and was only 28% for Kanigere area. Whereas sunshine at 16:00 hrs was 86% area at Kanigere followed by 60% and 6% area for Attadhat and Khakal respectively (Table 2).

Table 1 Area under kharif crop using various managements Unit: m^2

Crop	Site		
	Kanigere	Attadhar	Khakal
Maize	710	380	290
Rice	360	260	160
Ragi	550	190	250
Okra	270	240	140
Grass	320	170	125

Table 2 Influence of aspect on extent of sunshine at three sites

Site	Aspect		Extent of sunshine (%)			Mean (%)
	Degree	Direction	08:00 hr	12:00 hr	16:00 hr	
Kanigere	200	South	28	68	86	61
Attadhar	140	East South	80	77	60	72
Khakal	90	East	68	71	06	48

3 Soil characteristics and moisture regime

The average slope was higher than 30% for all the three sites. However, the Attadhar area was relative flatter (32%) slope than the Kanigere and Khakal for which was 42 and 57% respectively. The soil depth was varying from 34.3 cm at Khakal to 47.6 cm at Attadhar. The soil condition was characterized as productive, moderately productive and degraded respectively for Kanigere, Attadhar and Khakal. The soil of first two sites having slight gravel but the Khakal site soil having more 40% gravel. This gavelliness resulted in lower organic carbon (0.62% only), lesser soil moisture during kharif as well as during Rabi (Table 3). No specific trend was observed micro – nutrient status of the soil of the sites (Table 4).

Table 3 Soil characteristics and moisture regime

Site	Slope (%)	Soil depth cm	Condition	Graveliness	OC, (%) 0 ~ 15 cm	Bulk density (mg/m^3)	Soil moisture, (%), 0 ~ 30 cm	
							Kharif	Rabi
Kanigere	42	40.5	Productive	Slight	0.94	1.40	22.8	16.0
Attadhar	32	47.6	Moderately productive	Slight	0.85	1.45	21.3	14.1
Khakal	57	34.3	Degraded	Severe	0.62	1.46	18.2	12.4

Table 4 Status of selected micro – nutrients

Site	Micro – nutrient content in ppm (0 ~ 15 cm)			
	Zn	Cu	Fe	Mn
Kanigere	1.7	2.4	71.1	36.6
Attadhar	1.1	3.2	48.2	34.1
Khakal	3.1	1.3	43.1	40.9

4 Productivity of crop

The productivity level of Kanigere and Attadhar area was relatively higher than the Khakal (Table 5). The Attadhar area gave higher productivity during kharif than Kanigere whereas during rabi the Kanigere area provided higher productivity. This was due to the higher soil moisture in the Kanigere area than Attadhar area (16.0% and 14.1% respectively). The finger millet productivity was higher among all the crop and was true to all the sites. However, significantly lower productivity of hybrid napier was obtained in the Kanigere area. The Khakal area which gave lower productivity of food crop gave relatively higher productivity of fodder crop.

Table 5 Productivity of crops **Unit: kg/hm^2**

Site	Kharif			Rabi				
	Upland rice	Finger millet	Maize	Wheat	Lentil	Pea	Toria	Hybrid napier
Kanigere	2,447	3,230	1,750	1,136	440	588	284	1,500
Attadhar	2,866	3,788	1,671	1,330	496	179	180	8,200
Khakal	2,005	2,697	840	763	381	244	148	7,300

The highest green forage during winter was harvested from Attadhar area followed by Khakal and Kanigere. The White grub infestation was veri severe in Kanigere area which adversely affected the green forage yield of napier.

The sites with low gravels, good soil depth and moderate slope was suited for cereal crops production like upland rice, finger millets and wheat. Whereas marginal lands were found suited for finger millets, lentil, toria and silvi – pasture combination of Morus alba + hybrid napier + winter grass. The energy balance of selected crop under the three sites has been given in Table 6.

Table 6 Energy (MJ) balance of different crops

Site	Energy component	Maize	Upland rice	Finger millet	Hybrid napier
Kanigere	Output	3,006	3,184	2,849	286
	Input	333	538	438	57
	Balance	2,673	2,602	2,411	229
Attadhar	Output	1,754	2,304	1,087	242
	Input	350	356	335	43
	Balance	1,404	1,948	752	199
Khakal	Output	864	1,048	816	156
	Input	101	228	253	31
	Balance	763	820	563	125

5 Runoff and soil loss

The runoff and soil loss during kharif season is presented in Table 7. The Khakal area resulted in higher runoff than the other two sites. This was expected because the area is characterized by higher slope and graveliness. This ultimately resulted in the lower soil moisture during rabi. In general maize and okra crop gave higher runoff than the other crops. However, no specific trend was observed. Similarly the maize and okra crop was found more prone to soil erosion.

6 Micro – watershed productivity at farm holding level

The component of site specific integrated farming systems is crucial in hill farming. The studies conducted at VPKAS has shown the path of improving the production in hill agriculture in a sustainable way in the upper catchments. This approach can be successfully scaled up and replicated for food, environment and economic security of the Himalaya.

Table 7 Runoff and Soil loss from the sites

Crop	Site					
	Kanigere		Attadhar		Khakal	
	Runoff (L/100 m^2)	Soil loss (g/lit)	Runoff (L/100 m^2)	Soil loss (g/lit)	Runoff (L/100 m^2)	Soil loss (g/lit)
Date: 26/08/04; Rainfall: 56 mm (24 h)						
Maize	59.9	4.50	95.5	5.50	165.5	6.50
Rice	138.1	2.50	93.4	1.50	120.4	5.00
Ragi	70.4	4.00	146.2	2.00	181.6	4.50
Okra	171.1	4.00	151.0	8.00	171.4	6.50
Grass	70.9	2.50	20.6	2.50	140.8	4.00
Date: 15/09/04; Rainfall: 53 mm (24 h)						
Maize	90.14	9.00	131.6	4.50	172.4	11.50
Rice	86.33	3.50	100.2	4.50	184.0	4.50
Ragi	63.8	3.50	60.5	4.00	33.6	3.50
Okra	185.2	7.50	143.5	4.50	198.1	4.50
Grass	21.4	4.50	74.7	4.00	—	8.00
Date: 22/09/04; Rainfall: 28 mm (24 h)						
Maize	—	—	—	—	87.0	1.20
Rice	—	—	173.3	0.40	94.3	0.80
Ragi	44.3	0.55	60.5	0.35	20.2	0.25
Okra	—	—	212.1	0.40	104.3	1.00
Grass	23.6	1.10	—	—	—	

7 Productivity grouping

The typical farm holding size prevailing in Kumaon hills of NWHR is 0.4 hm^2 area and is distributed over as many as 20 ~ 30 small terraces which size varies from 0.01 hm^2 to 0.06 hm^2. The area was grouped into high, medium and low productivity area to make the strategy for cultivation of diverse crops based on the potential of the area. The availability of soil moisture, organic carbon, kg of nitrogen in 1 m^3 of soil volume, soil erosion and availability of sunshine were selected as the criteria for grouping are given in Table 8.

Table 8 Productivity grouping based on soil and energy resources

Factor	High	Medium	Low
Soil Moisture(%)	12 ~ 16	10 ~ 12	6 ~ 10
Organic Carbon (kg)[1]	> 2 kg	1 ~ 2 kg	< 1 kg
Nitrogen(kg/m^3)[1] >	0.2 kg	0.15 ~ 0.2 kg	< 0.15 kg
Soil Erosion($t/hm^2/yr$)	< 10	10 ~ 15	> 15
Sunshine Coverage(%)	75 ~ 100	50 ~ 75	< 50

The productivity of field crops and fodder was obtained as 24.4 q/hm^2 and 20.8 t/hm^2, 16.3 q/hm^2 and 18.1 t/hm^2 and 14.6 q/hm^2 and 15.6 t/hm^2 respectively (Table 9). The Table 9 presents the farm holding productivity during rabi season (October to April) when farmer cultivates the best option. Based on the information collected from the on – farm experiments, the optimal land use ratio for food and fodder were computed as 3∶1, 3∶1 and 1∶1 for high, medium and low productivity groups. Low productivity area can be recommended for extensive fruits cultivation such as Pear, Peach, Plum and Citrus. These plants started fruiting by 7th year and provided leaf fodder by 5th year. Therefore the productivity grouping of land resource and cultivation of crops accordingly is essentially required for optimal utilization of land resources and sustaining the productivity.

Table 9 The farm holding productivity (0.4 hm^2), Rabi Season (If the farmer cultivates best options)

Crop	High	Medium	Low
Field crops (Wheat, Lentil, Toria)	24.3 q/hm^2 9.7 $q/0.4\ hm^2$	16.3 q/hm^2 6.52 $q/0.4\ hm^2$	14.6 q/hm^2 5.8 $q/0.4\ hm^2$
Fodder (Hy. Napier + Winter Rye)	20.8 t/hm^2 8.3 $t/0.4\ hm^2$	18.1 t/hm^2 7.2 $q/0.4\ hm^2$	15.6 t/hm^2 6.2 $t/0.4\ hm^2$
Land use options (Food: Fodder)	3∶1	3∶1	1∶1
Food Fodder	7.3 q 2.1 t	4.9 q 1.8 t	2.9 q 3.1 t
Fruits – By 7th yr (Pear, Peach, Plum, Citrus, –36 trees)	8.7 q	5.9 q	4.5 q
Leaf fodder – 5th yr (Alnus, Bauhinia Grevia, Quercus – 36 tr)	0.66 t	0.60 t	0.48 t

8 Conclusions

Greater degree of sustainability in marginal lands was possible. Cultivation of suitable crops could reduce the production gap due to constrained agro – ecosystem. Yield level of 80% high productive system could be obtained in lentil whereas it was only 55% in case of wheat similar conditions. Improvement in production due to moisture conservation and nutrient in wheat was 70% as compared to only 35% obtained under better growing condition, with a basic level of 1 t/hm^2.

Thus, the farm holdings in hill region, with moderate slope, good soil depth and low gravels, were suited for cereal crop production like upland rice, finger millet and wheat. Marginal lands haring steep slopes, shallow soil depth and gravels were suited for finger millet, lentil, toria and silvi – pasture system of Morus alba + hybrid napier + winter rye grass. Adoption of location specific farming system is expected to impart food, environment and economic security in the Himalayan Region.

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Ecological Water Requirements and Available Quantity of Transferable Water Analysis in Yalong River of West Route of South – to – North Water Transfer Project

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Abstract: The general situation of West Route of South – to – North water transfer project is briefly introduced, and the advance of study on ecological water requirements is simply reviewed. Based on the particular condition of Yalong River Basin, on the principle of analyzing ecological flow, several methods are chosen and used to calculate the ecological flow at the damsite Reba, and then the available quantity of transferable water is estimated. The results show that the ecological flow is 36.3 ~ 46.8 m^3/s, and the available quantity of transferable water is $42.30 \times 10^8 \sim 45.62 \times 10^8$ m^3 accounting for 69.6% ~ 75.1% of normal annual runoff.
Key words: ecological water requirements, West Route of South – to – North water transfer project, available quantity of transferable water, ecological protection objective

Water resources in China are characterized by uneven regional distribution, more frequently in the South than in the North. Serious water shortage in Yellow River and Northwest China restricts local economic development and causes a series of ecological and environmental problems, such as soil and water loss, vegetation degradation, land desertification, and so on. Water has been the lifeline for Yellow River and North China. West Route of South – to – North water transfer project plans to divert some water from upper reaches of Yangtze River into Yellow River, which aims to solve the lack of water resources of Qinghai, Gansu, Ningxia, Inner Mongolia, Shanxi and Shaanxi six provinces. This great project has significant effect on the economy and entironment of Northwest China. However, the west routing area is in the east of Tibet Plateau, a typical ecotone where the ecosystem is liable to be destroyed because of varied geomorphology, changeable climate and various species in this ecological transitional zone. Once the water transfer project is put into practice, the flow in lower reaches within a certain distance from damsite will significantly decrease. In order to protect the ecological environment and local development at the greatest level, as well as to maximize engineering benefit, a study must be carried out to analyze and calculate ecological water requirements and available quantity of transferable water of involved rivers.

1 Introduction

1.1 West Route of South – to – North water transfer project

West Route of South – to – North water transfer project is a strategic engineering plan for involving the water shortage in whole Northwest China and some other areas in North China. Water will be transferred from Tongtian River (upper Yangtze River), Yalong River (branch of Yangtze River) and Dadu River into Yellow River. According to the programming, West Route project is divided into three steps: In the first period 40×10^8 m^3 water will be diverted from Yalong River and 5 branches of Dadu River, in the second one 50×10^8 m^3 water from Yalong River and in the 3rd one 80×10^8 m^3 water from Jinsha River. In the whole West Rout project 170×10^8 m^3 water will be transferred before 2050. From the planning modified recently, the first and the second period has been combined as a new "first period" in which the starting point of water routing is Reba damsite (at main stream of Yalong River), and then through water diversion structures and tunnels water will arrived at Aan damsite of Daqu River (branch of Yalong River), Renda damsite of Niqu River (branch of Yalong River), Luoruo damsite of Sequ River (branch of Dadu River), Zhuanda damsite of Duke River upper – stream, Huona damsite of Make River upper – stream, Keke damsite of Ake River, and finally to Jiaqu River (branch of Yellow River). In this new "first period" volume of water transferred is about 80×10^8 m^3 which includes 42×10^8 m^3 from Reba damsite of Yalong River.

West Rout project is a large – scale interbasin water transfer. But, from the view of ecosystem and environment, it is a complicated systems engineering on ecology. Besides the natural flow of rivers and water consumption by local people, ecological water requirement is one vital restrictive factor effecting available quantity of transferable water. Negative influence of water transfers on ecosystem and environment draws more people's attention, also becomes a study hotspot of researchers.

1.2 A brief review of ecological water requirements

Studies of ecological water requirements originated in foreign countries in 1940s and later a series of methods were achieved. However, there was no clear definition of ecological water requirement that was accepted by most researchers. Because of the difference of individual objects and comprehensions, many concepts were explored, e. g. water requirements of ecosystem, environmental flow, instream flow, low flow. In this period, emphasis was placed on rivers and quite a number of methods were put forward only for riverine ecological protection objectives.

In China with the rapid improvement of social economy in recent twenty years, degree of disturbance to river system is higher than any other countries around the world. Rational utilization of water resources and ecological protection has become a crucial issue. So, more attention is directed to ecological water requirements and much research work has been done. On the whole, this task is still on the starting stage in China. A lot of concepts about ecological (environmental) water requirements, consumption, or using, are not discriminated clearly. In 1989 the concept of ecological water requirement was firstly proposed by Tang in his study of water resources and oasis construction in the Tarim Basin. In 1990 environmental water using was given as "water for improving water quality, harmonizing ecology and beautifying environment" in "Encyclopedia of Chinese Water Conservancy". As one type of water using ecological water requirements must be considered when water resources planning are carried out in fragile ecological environment regions. This mandatory item was written in the trade standard "Environmental impact assessment of river basin planning" (SL45 – 92) by the Ministry of Water Resources of China in 1993. Tang (1995) discussed the necessity of studying ecological water requirements in the research of water resources utilization and oasis in Xinjiang oasis. And in the 21st Century, research on ecological water requirements is more active. Li et al. explained the connotation of ecological water requirements in the study of in Hailuan River Basin. Yan et al. analyzed and computed the ecological water requirements of riverine ecosystem in East Liaohe River Basin. Liu put forward the principle of four great balances concerning ecological water requirements: water – heat balance, water – salt balance, water – sand balance and regional water and supply – demand balance. Xia et al. considered that the ecological water requirement is objective water demand which aims to keep self – survival and ecological functions of ecosystem and to achieve one certain entironmental quality goal. This opinion was given based on the concept of hydrological cycle and the new theories of ecohydrology. Today, a great deal of theories and methodologies about ecological water requirements are burn, which becomes a popular branch of hydrology at home and abroad.

2 Ecological water requirements and available quantity of transferable water analysis

2.1 General characteristics of Yalong River Basin

Yalong River Basin (Fig. 1) is situated in the south of Tibet Plateau, between N26°32′ ~ N33°58′ and E96°52′ ~ E102°48′. Total area is about 12.8×10^4 k m^2 (wide 100 ~ 200 km, length about 900 km). Within the boundarior of sichuanis part approximately 11.63×10^4 km^2. It borders Dadu River eastward, Jinsha River westward and Yellow River northward (Sec Fig. 1).

Terrain and landform: In the basin, the topography of north, west, east are mantains and plateau with the elevation 4,500 m to 5,000 m, and the south tip of to pograph in dines to south, the elevation falls 4,400 m to 1,500 m. The rivers undercut intensely, the total nead is 4,420 m.

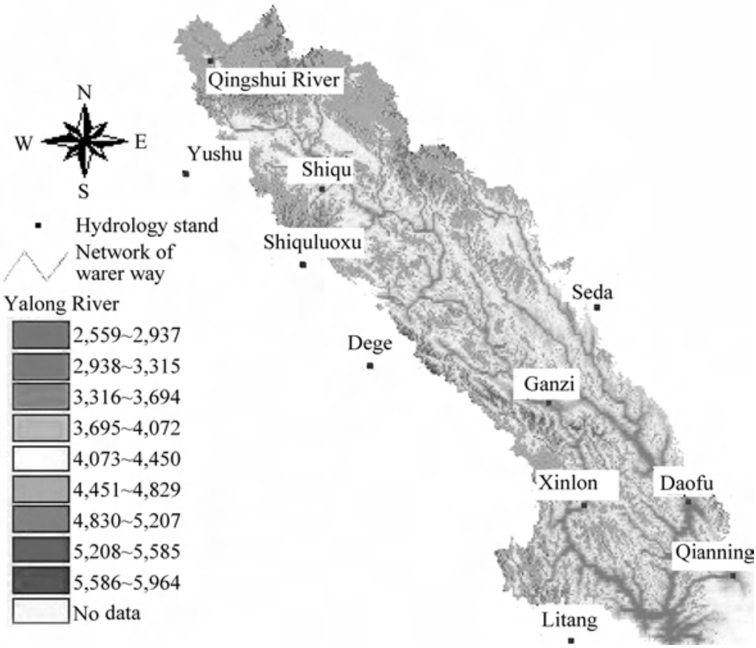

Fig. 1 Yalong River Basin

Climate and hydrology: As the plateau – climate of west Sichuan, climate in Yalong River Basin is quite complicated which is variable in both horizontal and vertical orientations. Wet season (May to October) and dry season (November to next April) differ obviously. The temperature decreases from south to north and east to west. The normal annual precipitation is about 600 ~ 1,800 mm, and depth of runoff varies from 300 mm to 1,000 mm.

Soil and vegetation: About six types of soil is included, alpine meadow soil, subalpine meadow soil, alpine frost desert soil, cinnamon soil, alpine steppe soil, mountain shrubby meadow soil and brown soil. The spatial distribution of soil types lies on the altitude and water – heat conditions. The vegetation is mainly composed of forest, brushwood and meadow.

Land use: Grassland accounts for more that 68%, forestland 20%, farmland, water area and other land types about 11%. From 1990 to 2000, land use changes not markedly.

Fish: According to the records and investigations, there are 29 species of fish (4 families, 3 orders). The dominant species is Schizothorax and Triplophysa; few Sisoridae exist and no other groups are discovered (Wu, 2007, Postdoctoral Report).

2.2 Selection principles for calculation of ecological water requirements

For different objects or goals of ecological protection, many methods are put forward for riverine ecological water requirements. These methods have various advantages and disadvantages when applied in certain fields. In general, these methods can be divided into hydrology – based methodology, hydraulics – based methodology, ecology – based methodology and synthesis methodology. And in these four methodologies, numerous methods are contained. According to the actual situation of North – to – South water transfer Liu (2007) sets the flowing principles to select methods of ecological water requirements.

(1) Taking as many methods as possible. Most methods available will be considered because each method perhaps emphasizes one interested factor. Using more methods can help to get an all – sided and objective result.

(2) Preferring these methods not depending on too much data. The region of North – to – South water transfer is in data rare basin where data series are short or incomplete. Some methods are unable to work. For instance, almost no ecology – based method can be carried out because of lack of enough ecological data.

(3) Getting rid of the methods not fitting for this study area. Many methods are developed for the characteristics of certain regions, or aim to deal with one detail ecological and environmental problem.

By these principles above, five methods are selected: φ Tennant (Montana) method, κ Texas method, λ basic entironmental water requirement method (minimum discharge method), μ wetted perimeter method, ν hydraulic radius method.

2.3 Results of calculation of ecological water requirements

Tennant method takes a given percent of annual mean discharge as recommendatory ecological flow. Generally, it is thought that 10% and 30% annual mean discharge can fill the minimum and all requirements of fish respectively. Texas method determines the minimum flow by the ratio of monthly mean discharge. Considering the water demand characteristics of fish, or variation coefficient of monthly discharge series, a rational ratio will be set. BF method generates a new series of the minimum values of monthly mean discharge, and treats the average of this series as ecological discharge. The monthly discharge data (1956 ~ 2004) of Reba station are needed to estimate the ecological water requirements of Yalong River with these three hydrology – based methods.

Wetted perimeter method calculates the ecological water requirements by the relationship of wetted perimeter and discharge. Firstly, the curve of perimeter – discharge will be described, and then a breakpoint where wetted perimeter changes outstandingly to the increase of discharge will be find out by slope or curvature method. The discharge indicated by this key breakpoint is the ecological discharge. During this course, the data about river section, monthly water level and discharge are necessary. In order to get the ecological water requirements of Reba, the data of river section at Ganzi station in 1965 ~ 1987 are chosen (no section data at Reba station) which shown in Fig. 2. And then the relationship curves of wetted perimeter – water level, water level – discharge (Fig. 3), wetted perimeter – discharge (Fig. 4) will be got. On the cure in Fig. 4 the breakpoint where the slope is most closed to 1 is that we want. The discharge of this point is the ecological discharge at Ganzi station. Finally, convert this value from Ganzi to upper Reba. The ecological water requirement at Reba is 37.6 m^3/s.

Hydraulic radius method is a hydraulics – based method which based on the definers of ecological velocity and ecological hydraulic radius. For a given river section, the ecological hydraulic radius can be computed by Manning formula, and then the ecological discharge can be estimated. Here, the ecological velocity v_{eco} is defined as the minimum velocity in channel that achieves one certain ecological protection objective and keeps the basic ecological functions

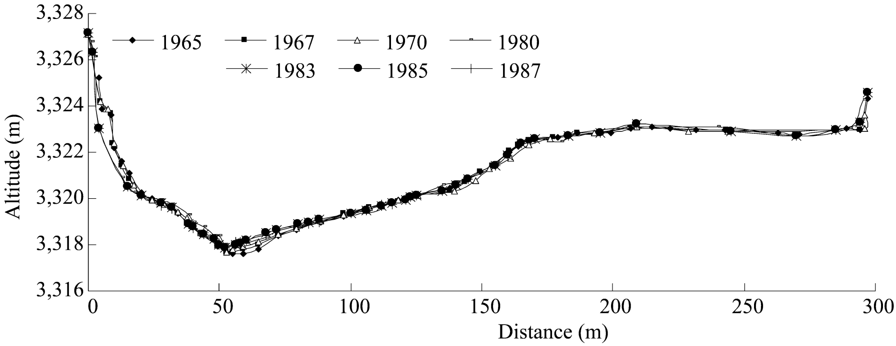

Fig. 2　River section at Ganzi Station

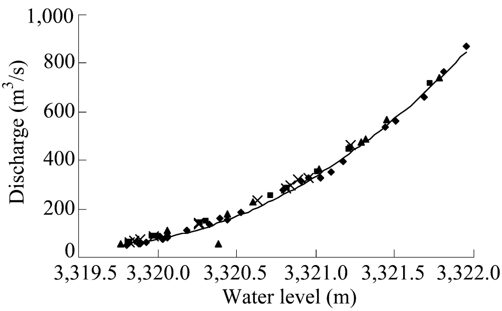

Fig. 3　Curve of water level – discharge at Ganzi

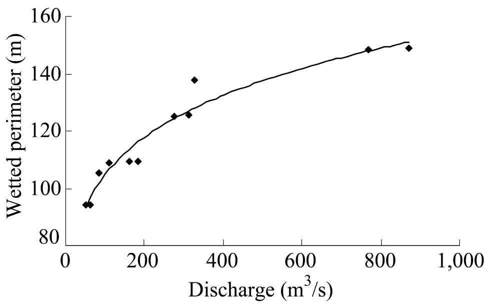

Fig. 4　Curve of wetted perimeter – discharge at Ganzi

working. For one given value of v_{eco}, the corresponding ecological hydraulic radius R_{eco} will be found out by the formula $R_{eco} = n^{3/2} \cdot v_{eco}{}^{-3/2} \cdot J^{-3/4}$ when roughness coefficient n and hydraulic slope J is known. At the same time, the relationship curve of discharge Q and hydraulic radius R can be got because of the field data about river section and discharge. On this $Q-R$ curve, the discharge against R_{eco} is the ecological discharge Q_{eco}. From the field investigations, the rational velocity is 0.45 ~ 1.74 m/s for the dominative fish in Yalong River. So in the following calculating steps $_{veco}$ is recognized as 1.0 m/s, $n = 0.029$, and $J = 10/10,000$. By Manning formula and $Q-R$ curve (Fig. 5), Qeco at Ganzi station is 61.81 m^3/s and the ecological discharge at Reba damsite is 36.3 m^3/s.

The results of ecological water requirements calculated by the 5 methods are shown in Fig. 6.

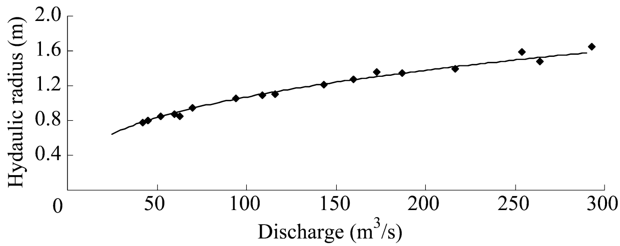

Fig. 5 Curve of discharge – hydraulic radius at Ganzi

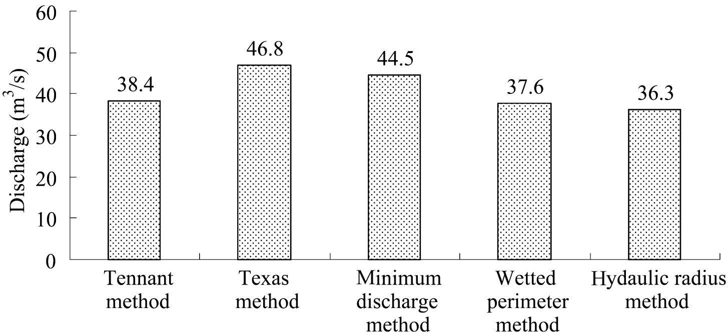

Fig. 6 Results of ecological water requirements at Reba in Yalong River by 5 methods

The five values of ecological water requirements by 5 methods are close, between 36.3 ~ 46.8 m^3/s, accounting for 18.9% ~ 24.4% of normal annual runoff (191.8 m^3/s).

Taking 20% of normal annual runoff as the minimum ecological discharge Tennant method gives attention to the water requirements of fish during the breeding season and growing season. BF method focuses on the low flow, and believers that riverine life adapts well to the natural variety of flow. The field investigation shows effect of human activity on the study reach is quite limited. The shape of river sections at Ganzi is similar to parabola, and the river bed is stable and single. So there is a stable relationship between wetted perimeter and discharge that the key breakpoint can be found out exactly. Hydraulic radius method has a good theoretical foundation, and emphasizes the channel information (hydraulic radius) as well as the habitat condition (ecological velocity) for specific protective objects keeping their ecological functions. In Yalong River, the protective object is Schizothorax, and the special habitat condition is the velocity of flow. In Texas method, different seasons are treated by different ratios. Actually the breeding reason is from March to April for Schizothorax and from August to September for Schizopygopsis malacanthus. Therefore, the ratios are set 30% during March to September, 10% during October to next February. The ecological water requirements of each month at Reba in Yalong River by Texas method is shown in Table 1.

Table 1 Ecological water requirements of each month at Reba in Yalong River (by Texas method)

Month	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
Ecological discharge (m^3/s)	16.7	27.6	50.9	90.3	122.6	96.4	104.2	25.3	12.6	6.6	4.6	4.5
Percent	30% monthly mean discharge (breeding season of fish)							10% monthly mean discharge (growing season of fish)				

From the analyses above, it is concluded that all these five methods aim to specific ecological protection objects or objectives, and the final results are credible. So, at Reba damsite of Yalong River the minimum ecological discharge is 36.3 ~ 46.8 m^3/s, and the corresponding ecological water requirements are $11.50 \times 10^8 \sim 14.82 \times 10^8$ m^3.

2.4 Analysis of available quantity of transferable water

As a result of unique location, low population density and undeveloped economy in Yalong River Basin, human water demand (industrial, agricultural and domestic water supply) is low which is about 5% ~7% of river runoff. Here, under the condition of annual normal runoff, taking 6% of river runoff as human water demand, and deducting the ecological water requirements, the reminder is the water transferable. Shown in Table 2, the mean available quantity of water transferable at Reba is $42.30 \times 10^8 \sim 45.62 \times 10^8$ m^3, and the ratio is 69.6% ~75.1%, which can fulfill the programming.

Table 2 Available quantity of water transferable at Reba damsite in Yalong River

Natural runoff		Minimum ecological water requirement		Human water consumption ($\times 10^8$ m^3)	Quantity of water transferable ($\times 10^8$ m^3)	Ratio of amount transferable
Discharge (m^3/s)	Runoff ($\times 10^8$ m^3)	Discharge (m^3/s)	Amount ($\times 10^8$ m^3)			
191.8	60.77	36.3 ~46.8	11.50 ~14.82	3.65	42.30 ~45.62	69.6% ~75.1%

3 Conclusions

In this paper, the general situation of West Route of South – to – North water transfer project is briefly introduced, and the advance of study on ecological water requirements is simply reviewed. Based on the particular condition of Yalong River Basin, on the principle of analyzing ecological flow, several methods are chosen to calculate the ecological flow at the damsite Reba, and then the available quantity of transferable water is estimated. The results show that the ecological flow is 36.3 ~46.8 m^3/s, and the corresponding minimum ecological water requirements are $11.50 \times 10^8 \sim 14.82 \times 10^8$ m^3 and the available quantity of transferable water is $42.30 \times 10^8 \sim 45.62 \times 10^8$ m^3 accounting for 69.6% ~ 75.1% of normal annual runoff. All these five methods aim to specific ecological protection objects or objectives, and the final results are credible.

Because ecological water requirement is a new field which relates to the structure, composition, function and factors of water cycle, and in the region of West Rout of South – to – North water transfer project unpredictable complexity and uncertainty exist, the results in this paper need more work to do. It is indeed necessary that more efforts should be made to study the ecological water requirements in aspects of building ecological protective goal system, developing new methods, evaluating water diversion risk, and so on.

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Basin – based and Ecological Tendency of Reservoir Regulation

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Abstract: With the increasing utilization of water resources, the overall development of cascade reservoirs and the rising voice of restoring river eco – environment, reservoirs' function presents basin – based and ecological tendency, their regulation mode should be advantageous of eco – environment. The paper puts forward that existing reservoir ecological regulation mode should be studied, compensation mechanism of ecological regulation should be established and reservoir ecological plan should be prepared in order to realize reservoir ecological regulation. Finally the paper brings forward the feasibility of implementing ecological regulation in the Yellow River and some issues needed to study.

Key words: water management, reservoir ecological regulation, ecological tendency, the Yellow River

1 Introduction

The history of human beings shows that human development history is a history of adapting the nature and rebuilding the nature. As the source of life and one of motive powers of social productivity, water plays an extremely important role. Water conservancy project is an important means to adapt the nature and rebuild the nature, and has an important position on human development history. Some significant or widely disputed water conservancy projects have gone down to history together with their constructors. 4,000 years ago, Dayu controlled flood and was praised for his achievement. The Dujiangyan project built in Warring States still benefits west Sichuan plain. The Sanmenxia reservoir with unceasing disputations from planning to running has become the focus again since Weihe river flood in 2003, but this time the focus is to discard it or to reserve it. The famous Three – Gorges Project on the Yangtze River is on the way, and the South – to – North Water Transfer Project is stepping up to plan and construction. When we are excited for the construction of water conservancy projects, the agitation of dam explosion is surged in USA at the same time. The disputations of water conservancy projects may not stop forever, neither do the human beings' steps of adapting and rebuilding the nature.

The 21st century is called as the century of water, because water resources are the shortest natural resource and an important protection factor of national or regional development. Water resources management problem is very complex, concerning a lot of sectors and industries and involving different benefits, such as pollution control, ecological protection and water saving, etc. The regulation function of reservoir plays an important role in basin water resources integrated management. Along with emergence of series of problems, e. g. the aggravation of water resources demand and supply contradiction, the aggravated loss of drought and water pollution, and the loss of river function due to water quality deterioration, water safety and basin sustainable development have been pushed to a higher level. As an important means of basin water resources regulation, reservoir regulation presents basin – based and ecological tendency according to scientific notions of water resources integrated management and maintaining the healthy life of the river. That is, as to reservoir, especially to the large – scale reservoirs, their function has changed from flood control, water supply and power generation to promoting basin sustainable development and maintaining the healthy life of river.

2 Changes of reservoir regulation

Along with the severe contradiction of water supply and water demand, reservoir regulation is more and more involved in the whole basin water resources integrated regulation, its original design running method is more and more interfered by the integrated regulation. Its role is not just localized on original comprehensive utilization objects, but presents basin – based and ecological characteristics. The reservoir regulation does not seek for its benefit maximum any more, but brings into integrated regulation of the whole river basin and becomes the key means of basin water resources integrated allocation. Its goal is to meet the requirements of sustainable development of the whole river basin.

Take the cascade reservoirs of upper reaches of the Yellow River as an example, under the condition of long – term shortage of water in 1990s, water transfer with long distance from large – scale reservoirs in the upstream were implemented many times in order to lessen difficulties of socioeconomic development and crisis of eco – environment due to "zero – flowing" of the lower reaches of the Yellow River, which got significant social and economic benefits. Although the cascade hydropower stations in the upper reaches of the Yellow River sacrificed their power benefits, they played an essential role in safeguarding socioeconomic development and people's stable life in the lower reaches and in alleviating crisis of ecological environment. Therefore the original regulation mode of mainly generating electricity for upstream cascade reservoirs has expanded to whole basin due to water resources integrated regulation, including safeguarding water use for production and living in the downstream, alleviating eco – environment crisis of zero – flow sections in the lower reaches, etc. Since water resources integrated regulation was carried out in the Yellow River basin in 1999, the water supplement action to the lower reaches has changed from emergent action to systematic and long – term measure.

At present, according to development of reservoir regulation, it can be single reservoir regulation for flood control, water supply and power generation, cascade and unite reservoirs regulation with many reservoirs or reservoir group, basin integrated regulation, and ecological regulation. Minister Wang Shucheng pointed out to study the ecological regulation problem in January, 2006. Ecological regulation is the newest development stage of reservoir regulation and focusing on satisfying basin water resources regulation and river ecological health, related research is developing now.

3 Reasons

The function change of reservoir regulation is due to 3 reasons.

Firstly, the unceasing rising of water resources utilization degree promotes basin – based tendency of reservoir regulation.

According to statistics, the water resources utilization degree in China is very high, there in Haihe River has reached 78%, Huaihe River has reached 37% and the Yellow River has reached 72%, all of them have exceeded or approached the development upper limit of international standard which is 40%. The unceasing rising of water resources utilization degree aggravates the contradiction of water supply and demand, strengthens the role of water resources optimized allocation and then upgrades the function of reservoir in basin water resources regulation which emphasizes particularly on basin water resources regulation. Therefore, with the unceasing rising utilization degree of water resources and reinforcement of the function of water resources optimal allocation, reservoir regulation not only localizes original power generation, flood control and water supply, but also presents basin – based tendency.

Secondly, cascade development of reservoirs strengthens basin – based tendency of reservoir regulation.

With the increasing supply and demand contradiction in energy, the restriction of chemical fuel for environmental protection and the long – term consideration about energy safety, waterpower project, which has the characteristics of cleanness, low cost, long life and huge comprehensive benefits, has become important energy source of our country, and also become main field for many enterprises to investigate and invest. Especially with the reform of the power system in China, the advantages of waterpower project in "separation of power network and electricity generating companies" and "on – grid price bidding" becomes an important breakthrough and then a new climax of waterpower construction rises in the whole country. Most reservoirs have formed the pattern of cascade development, such as Yangtze River, Jinshajiang River, Lancangjiang River, Wujiang River, the mainstream of the Yellow River and Taohe River, etc. The cascade development of these rivers has extensive and profound affects for the basin, and cascade reservoirs regulation influences the basin deeply.

Thirdly, restoring basin eco – environment triggers ecological tendency of reservoir regulation.

Domestic scholars proposed project water conservancy, resource water conservancy and environmental water conservancy with the analysis of water resources supply and demand, in which project water conservancy denotes that water resources supply is mainly restricted by project ability, not restricted by water resources quantity; resource water conservancy means that the fact that water resources demand is larger than water supply leads to water resources scarcity, it needs to satisfy water demand through optimal allocation and water saving; environmental water conservancy denotes that water resources consumption threatens basin eco – environmental health and then causes zero – flow etc., it needs to take measures to maintain basin eco – environmental health. The experiments have started abroad to change reservoir regulation mode to restore basin eco – environment, e. g. flood peak was made to change the shape of water course through regulating Glenn reservoir of Colorado River in USA; the research and practice, which includes the reservoir group regulation strategy to meet eco – environmental requirement, has been carried out in Tennessee river; reservoir regulation was changed to fish protection and eco – environment protection in Volga river and Densit river in Russia. In China, reservoir regulation to improve and restore river eco – environment has already started. Wang Shucheng, Minister of Ministry of Water Resources, pointed out at the directors general's conference of national water resources department to do well the job of ecological and environmental protection in water conservancy engineering, to establish the regulation mode advantageous of ecological protection and to fully exert the function of water conservancy projects to protect ecology. In December, 2005, a forum of "restoring ecosystem of lower reaches through improving reservoir regulation" was hold to discuss the feasibility of restoring ecosystem of lower reaches and improving people's living standards through improving reservoir regulation and water facilities management. Now the Ministry of Water Resources has done a lot on protecting and restoring water ecosystem and has got significant achievements. For instance, experiments for 4 times of water and sediment regulation were made in order to enforce water resources integrated regulation of the Yellow River, which ensured the Yellow River no Zero – Flow for 6 years and discharged approximately 300 millions tons of sediments to the sea and then improved the flow capacity of the river channel. Comprehensive harnessing and water resources integrated management and regulation were carried out in some ecological fragile rivers such as Heihe River, Tarim River and so on, which has improved ecological restoration of the lower reaches. Emergency water recharge to Nansihu Lake, Zhalong Lake, Xianghai Lake, Baiyangdian Lake and other lakes or wetlands protects and restores ecosystem. Water transfer from Yangtze River to Tai Lake and floodgate and dam anti – fouling regulation in Huai River improve water quality and alleviate water pollution loss. Ecosystem protection and restoration experimental units in Guilin and Wuhan have put forwarded. Reservoir regulation plays an important role in restoring above water ecosystems. For instance, it has close relation with reservoir regulation that the Yellow River realizes no Zero – flow for 6 years and implemented water and sediment regulation for 4 times. Therefore restoring basin eco – environment leads to ecological trend of reservoir regulation, which has extended the function of reservoir regulation to the level of restoring river eco – environment.

4 New challenges

The function change of reservoir regulation results in new problems as follows:

The first problem is how to operate existing reservoirs to satisfy the new requirements of serving for basin water resources regulation and river ecological health.

Statistical data shows, up to 2003, there are already 49,697 reservoirs in the world with storage capacity of over 1 million m^3 or dam height of over 15 m, the country with most reservoirs built is China, USA, former Soviet Union, Japan and India in turn. China is the top country for reservoir construction and the previous reservoir construction just focused on natural disaster prevention and resources utilization and didn't take eco - environment into consideration. Therefore, the goals of reservoir regulation are flood control, power generation, irrigation, water supply, shipping and so on, its regulation mode was designed according to these goals. However, nowadays with the concept establishment of harmonious coexistence between man and nature and under the circumstance that water resources can not only improve socioeconomic development but also can maintain the healthy life of the river, so how to operate reservoirs to realize these goals is an urgent problem, including how to operate reservoirs to coordinate the requirements of economic society and ecological environment and how to operate reservoirs to restore and maintain the function of river ecosystem, etc. To satisfy new requirements of serving for basin water resources regulation and river ecological health, it is the most direct and effective way to adjust the existing reservoirs regulation mode, the new regulation mode is ecological regulation mode, which can realize the goals to meet water resources regulation and river ecological health. What is gratifying is that related research and practice have started in China and abroad, as mentioned above, USA and Russia adjusted reservoir regulation mode to satisfy ecological environment, China carried out the experiences of water and sediment regulation of the Yellow River, ecological water supplement to Heihe River and Tarim River, etc. However all in all, as reservoir ecological regulation just starts, its impacts on eco - environment is complex and related research foundation is weak, so it is necessary to strengthen the study on how to operate existing reservoirs to satisfy basin water resources regulation and river ecological health.

The second problem is how to readjust the benefit of different aspects with the change of existing reservoirs regulation mode.

The design regulation mode for previous reservoirs mostly did not take river ecological health into consideration and meanwhile each stakeholder's benefit has already well coordinated. If reservoir regulation mode changes, each stakeholder's benefit has to readjust. For instance, most reservoirs have the function of generating electricity, and have formed fixed regulation mode advantageous of electricity generation, power benefit is the main economic source of reservoir. If reservoir regulation mode changes according to eco - environmental requirements, it will directly affect its power benefit. For example, the upper reaches of the Yellow River is rich of water power, the cascade development benefits of water power is notable. In 1990s the lower reaches of the Yellow River suffered from Zero - flow, water was transferred from upper reservoirs to lower ones and power benefits was influenced. Integrated regulation started in the whole river basin in 1999, reservoir power benefits was influenced directly, benefit change needs to readjust. As pollution accident bursts in estuary, reservoir sluicing to dilute pollutant will affect power benefits. In addition, reservoir ecological regulation mode may generate new benefit stakeholders, e. g. the change of reservoir regulation mode could result in increment of flood control cost in the lower reaches, risks of flood loss and collapse in reservoir area. At present, with the environment of market oriented economy, it needs to put forward a scheme to adjust each stakeholder's benefits, e. g. after carrying out ecological regulation mode, compensation mechanism should be established to adjust benefits of each aspect.

The third problem is that planned reservoirs should change their design so as to satisfy the requirements of basin water resource regulation and river ecological health.

As for planned reservoirs and other water conservancy projects, it is necessary to emphasize their functions on rivers during the planning phase, on one hand, to satisfy the requirements of basin water resources regulation, on the other hand, to satisfy the requirements of river ecological health. For instance, as to the planned hydropower station, the minimal base flow must be restricted to avoid man - made dried river sections in the lower river channel resulted form peak shaving running of hydropower station.

5 Countermeasures

At present, the urgent issue to be solved is the reservoir ecological regulation, that is, to coordinate socioeconomic sustainable development and ecological health of rivers through optimizing reservoir regulation mode. As mentioned above, it is the most direct and effective way to achieve socioeconomic sustainable development and river ecological health through ecological regulation of existing reservoirs. However, current research foundation is weak, therefore it is urgent to start the study on reservoir ecological regulation. Major researches include:

Firstly, establish technical system for the reservoir ecological regulation, including theoretical foundation, techniques, countermeasure mechanism and evaluation system. The core is to establish a set of effective reservoir ecological regulation theoretical technical system. Its difficulty is to build up the eco – environmental response mechanism of reservoir ecological regulation.

Secondly, establish compensation mechanism of reservoir ecological regulation. Mainly study benefit change of stakeholders before and after reservoir ecological regulation implementation and compensation mechanism, study scientific and reasonable policy and management mechanism and put forward countermeasures.

Thirdly, develop reservoir ecological regulation practice. Continuously check up research results in practice, accumulate experience and perfect reservoir ecological regulation.

It is necessary and feasible to carry out reservoir ecological regulation in the Yellow River basin. On one hand, the water resources in the Yellow River basin is scarce and the contradiction between socioeconomic development and river ecological health is prominent, which has covered nearly all river problems, such as water resources shortage, sediment, flood control, eco – environmental problem, etc. Meanwhile there are numerous reservoirs in the Yellow River basin, so there are urgent requirements and good conditions to carry out ecological regulation. On the other hand, as the research on the Yellow River has started very early and the achievements are rich, e. g. the Yellow River has "87 water allocation scheme" and water resources integrated regulation has been carried out since 1999. All these research results on reservoir regulation and times of successful water and sediment regulations have provided foundation of theory and practice for reservoir ecological regulation. Therefore it is necessary to start the research on ecological regulation in the Yellow River basin as a threshold and then implement ecological regulation in China.

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Analysis of Food Security and Water Resources in Irrigation Areas of the Lower Yellow River

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Abstract: Food security to a great extent depends on irrigation. Irrigation along the Yellow River adjusts the water – requirement of crops, resulting in high and stable yields of grain, which guarantees significantly the region's food security. According to the water – requirement of crops downstream of the Yellow River, this paper analyzed the relationship between irrigation quantity and water resources of the Yellow River, and then discussed the problems that food security faced, finally brought forward the necessary countermeasures to guarantee the food security downstream the Yellow River.
Key words: the Lower Yellow River, irrigation, water – requirement, food security

Influenced by the climate, the investment, the price policy and such elements of uncertainty, the grain production often undulates greatly year by year. The margin of fluctuation has reflected the food security degree to a certain extent. The economists have defined the food security concept as "the ability of a country in satisfying the growing needs of food demand and the ability in withstanding various eventualities in food economy". The proportion of people and land in the Lower Yellow River is intense, the average amount of grain possession per person had been in a low level for a long time, and it was after the reform and open that the meal question was solved really. And it was until then that the average amount of grain possession per person surpassed the national average level. In future, the production structure and the social structure will have some fierce transformation, which would generate profound influences to the food security.

1 General situation of the irrigation areas diverted water from the Lower Yellow River

1.1 Irrigation area

The Lower Yellow River areas are important commodity grain production base in China. The agricultural population is 43,810,000, and the design irrigation area is 3,580,000 hm^2 (effective irrigation area is 2,580,000 hm^2, source – replenished irrigation area is 1,130,000 hm^2).

1.2 Crop species and irrigation system

The staple crops in irrigation areas of the Lower Yellow River consist of wheat, corn, cotton, paddy rice, oil plants, vegetables and so on, with duplication index of 1.75. Influenced by the geographical and climatic conditions and the planting custom, the way of management in this area and the crop's irrigation systems are not all the same. The time that Yellow River irrigation area mainly needs water is the spring irrigation from March to June, fall irrigation in the mid – september, and the winter irrigation in the first 20 days of December.

The wheat is growing usually from early October to mid – May of the next year, and the water required generally is 2,025 ~ 5,670 m^3 per hm^2, irrigated in 3 to 5 times across the entire growing period, with 450 ~ 1,200 m^3 per hm^2 for each time. The corn's growing period is from the beginning of June to mid – August, the general irrigation requirement is 525 ~ 3,000 m^3 per hm^2, 2 ~ 4 times of irrigation are needed across the entire growing period, and the irrigation quota every time is 450 ~ 1,050 m^3 per hm^2. The cotton's growing period is from the beginning of April to the late August, the general irrigation requirement is 900 ~ 3,000 m^3 per hm^2, 3 ~ 5 times, and the irrigation quota is 450 ~ 900 m^3 per hm^2. The paddy rice's growing period is from early May to early September, the irrigation requirement is 4,950 ~ 9,000 m^3 per hm^2, 4 ~ 7 times are needed, and the irrigation quota is 450 ~ 1,500 m^3 per hm^2.

1.3 Irrigation mode

The irrigation area of the Lower Yellow River is divided into two types: the normal irrigation area and the source – replenished irrigation area. According to the physical geography in different sections of the river and the water diversion conditions from the river channel, many kinds of irrigation pattern have been formed.

1.3.1 Gravity irrigation, with the combination of canals and wells

This pattern of irrigation area is distributed at the upper parts of the irrigation area along Yellow River, where the field supporting systems are in good conditions. The area of this kind of irrigation area occupies 20% to 25% of the total area of the lower Yellow River's irrigation areas. Above 50% of the Henan's irrigation area diverted water from Yellow River belongs to this pattern, and the proportion in Shandong is small, which is just 13% of the total.

1.3.2 Gravity irrigation, with the combination of canals and rivers

This pattern of irrigation area is distributed mainly in Heze, Liaocheng, Dezhou and Binzhou below Gaochun, and most of them are located at the middle and lower parts inside the irrigation area. The height difference between the channel's water table and the banks is small, and the sand is deposited intensively on its way. The water is transported through channels or ditches, and the built flood retarding projects can be used to pond the diverted water in advance and to irrigate by pumping separately. This can reduce the water volume diverted in drought period and increase the area of irrigation. This kind of irrigation has the advantages of small investment, fast effects and broad spread, which occupies 50% ~ 60% of the irrigation area in the Lower Yellow River.

1.3.3 Source – replenished irrigation mode of well irrigation primarily

This kind of irrigation pattern is developed in 1980s because the irrigation area is far away from the Yellow River and the local surface water are not enough, especially after many years' exploitation of ground water continuously, which caused the unceasing lowering of water table. This source – replenished irrigation mode plays a vital role in alleviating the serious shortage of local water resources to satisfy the food's water demand.

2 The problems that food security faced in water use

The irrigation farming in the Lower Yellow River plays a pivotal role in safeguarding the food security. But the shortage of the local water resources and the difficulties in development make the local Yellow River become the important water source. Along with the development of the agricultural irrigation in the Lower Yellow River, the irrigation area increases from 300,000 hm^2 in 1950's to the present 2,580,000 hm^2, and the water volume diverted directly from the Yellow River increases rapidly to 8, 800, 000, 000 m^3 at the beginning of the 21st century from 3,200,000,000 m^3 in the 1950's, and in 1989 the number has achieved 15,100,000,000 m^3, which shows that the water demand increased day after day.

2.1 The food production was influenced by the shortage of water resources

The Lower Yellow River is the area which suffers scarce water resources and frequent flood and drought disasters, and the spatial and temporal distribution of water resources is extremely imbalanced. The rainfall in the four months of flood season approximately accounts for 70% of the whole year, and the drought problem has become the prominent factor constraining the economic development in the Lower Yellow River.

The Yellow River belongs to the resource – lacked river, and the most runoff during the year is distributed in the flood season. The runoff from July to October in lower Yellow River occupies as high as above 60% of the year's total runoff, what's more, most of the runoff occurs as floods with high sand content, so it is difficult to use. The peak period of water demand in the lower agriculture farming is from March to May, but the natural runoff during this time just occupies 10% to 20% of the annual runoff. When it comes to 1990's, the supply and demand contradictory in the Yellow River is becoming more and more incisive. The water demand has surpassed the bearing capacity of the Yellow River, which can be seen from the fact that the cut – off of flow in the Lower Yellow River occurs frequently. Along with the quickening of the industrialization and urbanization advancement, the increase of industry and city water use takes over the amount of water for irrigation, which aggravates the shortage degree of grain production water demand.

Because of the insufficiency of the water resources and the unscientific diversion, the water resources along the Yellow River appears to be unbalanced in supply and demand, and the cut – off of flow occurs in the tributaries of the middle Yellow River such as Qin River, Yi River, Fen River, Dawen River, Yan River, Weihe River and so on one after another. In 1997 the days without flow at Lijin station in the lower Yellow River accounts for 226 in accumulation, and there are 295 days during that no flow enters the sea. The river section without flow extends upstream to Liuyuankou in Kaifeng, with the total length of 704 km, which has affected the industrial and agricultural production and the lives of the people along both banks. That caused the reduction scale of oil field production and the intense water supply, and affected greatly the grain production in the Lower Yellow River.

2.2 The faultiness of irrigation and drainage facilities and the low efficiency of water use in crop production

The management of irrigation water diverted from the Yellow River is still in a simple and extensive way while the water supply is in tension. The inconsistent irrigation projects, the aged channels and the backward irrigation technology made the use coefficient of irrigation water below 0.5, which restricted the development of agriculture related to the Yellow River. For example, the gross irrigation quota in Renmin Shengli Canal, Dagong and Sanjiazhai irrigation areas in Henan and Xingjiadu, Hujia'an, Bojili, Handun, Xiaokaihe, Caodian and Wangzhuang irrigation areas in Shandong reached 7,500 to 10,500 m^3 per hm^2, which is much higher than 5,100 ~ 6,600 m^3 per hm^2 in water – saving irrigation situation. Partial irrigation areas use water in daytime rather than night, and the waste water is too much, which intensifies the supply and demand contradictory of water resources in the Lower Yellow River.

In the Lower Yellow River the agricultural water use has been protected by the government, and high quota of subsidy has been allocated to the hydraulic infrastructure construction and water fee. The essential purpose is to reduce the farmers' burden, and finally to safeguard our food security. But under this kind of situation, the consciousness of the farmers to save water and input and output in production was weakened, and the phenomena of wasting and low efficiency have not been inhibited in the Lower Yellow River.

2.3 The serious siltation

The terrain of the irrigation area in the Lower Yellow River is smooth, and the gradient of the ditch is gentle. Massive silts entering the irrigation area caused the channel's siltation. In Henan the channel gradient is big, and the silt delivered to the field can reach 43.3%, while in Shandong the channel gradient is small, and the silt delivered to the field only occupied 8.8%. The silt entered the drainage system is 11.5% and 6.5% respectively, and majority of silt settle down in the channel, which causes the reduction of farming land, soil desertification and destruction of ecological environment and affects the irrigation area's normal work.

The inflow to the Lower Yellow River contains much sediment of fineer particle size. Under the condition of the higher level of the riverbed and the siltation accumulated year by year, the silt content and the particle size into the channel are nearly the same as they are in the inflow. Except influencing the channel siltation and increasing the production burden, the massive silts entered the ditches are improperly dealt with and cause serious adverse effects on the ecological environment and social economy both inside and outside the irrigation areas. Because the low – lying lands for sedimentation become less, massive silts diverted from the Yellow River settle down in all levels of ditches and waste channels, so that a great quantity of manpower and materials have to be devoted every year to clear the siltation, and the silt cleared is left on both banks, which not only occupies large farming lands, but also causes land desertification and serious worsening of ecological environment in the irrigation area, and restrictes the development of the diversion from the Yellow River.

2.4 The change of riverbed, canal siltation, and capacity reduction of water diversion

Since 2002, five experiments of water and sediment regulation in the Yellow River have been successively carried on, which provided some important scientific values to know the water and sediment movement rules, to enhance the regulative ability of water and sand, and to verify the modern methods to manage the Yellow River and so on. The water and sediment regulation caused the undercut of the lower Yellow River course generally, which caused the water level to drop 0.87 to 1.93 m under the condition of the same flux and caused the reduction of water diversion ability of the sluice.

The low water level in the canal head caused the slow – down of the flow and the reduction of silt – carrying ability, which aggravated the channel siltation and in turn affected the canal head's ability in water diversion. Because of the riverbed change, partial sluices appeared to be out of the river one after another in recent years, which worsened the water diversion condition and caused the obvious atrophy of the sluices in the lower Yellow River as a result of not clearing the ditches in time.

3 Water demand and water resources of the irrigation area in the Lower Yellow River

3.1 Water demand for irrigation

The water demand in the irrigation area of the Lower Yellow River all relates with precipitation, irrigated area, planting structure, irrigation system, inflow of the river, ground water extraction level and so on. Supposing there are K kinds of crop, the water demand of a certain time period will be:

$$W_i = \sum_{j=1}^{K} m_{ij} A_j / \eta_w$$

where, W_i is water demand at time i; m_{ij} is irrigation quota at time i for crop j; A_j is planting area of crop j; η_w is irrigation water utilization factor. For the entire period of duration or the whole year:

$$W = \sum_{i=1}^{n} W_i$$

Through computation, the total water demand of the crops in the Lower Yellow River for one growing season is approximately 13.083 billion m^3.

3.2 Yellow River's water resources

The multi – annual average amount of runoff from 1951 to 2003 at Huayuankou station was 39.1 billion m^3. Compared with the period from 1951 to 2003, the monthly runoff from 1991 to

2003 was generally smaller, among which the runoff from July to November only occupied 39% to 52% of the multi – annual average runoff. In the spring irrigation period (from March to May) the runoff only occupied 80% of the corresponding period.

Compared with the period from 1991 to 1995, the average annual runoff was reduced by 22% from 2001 to 2003. Except June, October and November, the runoff in the rest time all reduced somehow, in which it was reduced by 75% in August. In the spring irrigation period (from March to May) the runoff was reduced by 21%. See Fig. 1.

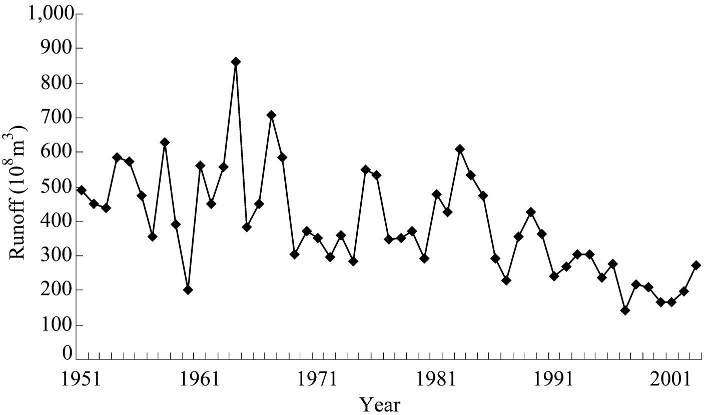

Fig. 1 Runoff change at Huayuankou year by year

3.3 Local water resources

3.3.1 Precipitation

Precipitation is an important source to supply surface water and ground water in the irrigation area. The rainfall in the irrigation areas of the Lower Yellow River ranges between 560 and 680 mm, and the average multi – annual precipitation in flood season (June to September) is 418 mm, accounting for 72.6% of the average annual precipitation. At the peak time in the spring irrigation (from March to May) the precipitation is 88 mm, accounting for 15.3% of the average annual precipitation. The average multi – annual transpiration is 1,100 ~ 1,300 mm, average multi – annual temperature 12 ~ 14 ℃, and frost – free period last for 180 ~ 210 days.

The precipitation concentrates in a year, but varies too much year by year, and the ratio of the maximum and minimum annual precipitation is between 2.52 ~ 4.79. It is difficult to make full use of the local precipitation under the present situation, and massive precipitation is drained outside.

3.3.2 Local ground water resources

The ground water in the irrigation area of the Lower Yellow River is mainly recharged by precipitation, and moreover, channel's leakage and irrigation infiltration and so on. The exploitable ground water resources in the irrigation areas totals in 10.92 billion m^3. The exploitation of the ground water tends increasing, and in Henan the exploitation's distribution is uneven, and in Shandong Province the mining degree is low besides the estuary area. The mining degree near the Yellow River is low because it is convenient to divert river water, but the mining degree is high in faraway area.

3.3.3 Local surface water resources

Majority of the surface water resources in the irrigation areas of the Lower Yellow River comes from the runoff produced by the flood season's rainstorm, due to inadequate storage condition in the plain area, it is of big difficulty to use the surface runoff. The natural runoff at guaranteed rate of 75% is 1.9 billion m^3. At present, the prominent question facing the irrigation area's surface water use is water pollution that seriously influences the surface water use. The local surface water used in the irrigation area actually in lower irrigation area is approximately 0.76 billion m^3.

4 Analysis of water use in the irrigation areas of the lower Yellow River

4.1 Water diversion quantity from the Yellow River

The average annual water diversion quantity from the Lower Yellow River is 7.24 billion m^3, showing a growing tendency, 3.2 billion m^3 in the 1950's, 3.79 billion m^3 1960's, 8.12 billion m^3 in 1970's, 10.64 billion m^3 in 1980's, 9.37 billion m^3 in 1990's and 7.8 billion m^3 in average after 2000. See Fig. 2

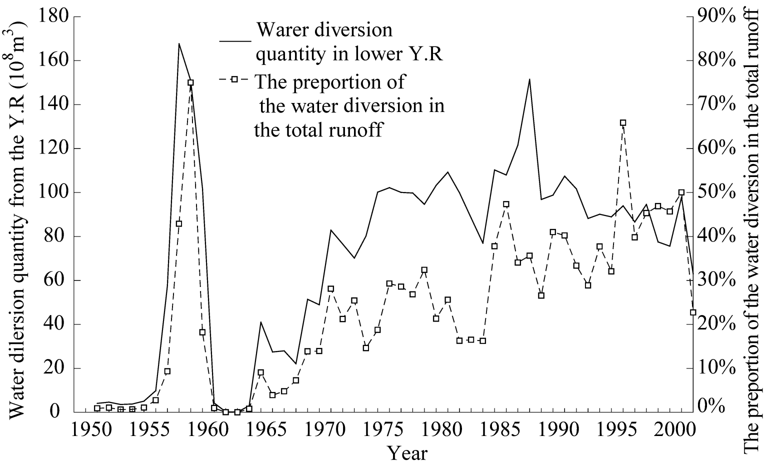

Fig. 2 Change of water diversion quantity year by year in Lower Yellow River

The proportion of the water diversion quantity in the total runoff in the lower Yellow River is in a trend of escalation gradually. During the years from 1970 to 1989, the annual water diversion quantity from the Lower Yellow River is increased from 5.14 billion m^3 in 1970 to the historical maximum value of 15.15 billion m^3 in 1989, which is increased by near 2 times and the average annual increase rate is nearly 6%. After 1990, the water diversion quantity from the Lower Yellow River recedes slowly, and the average annual water diversion quantity is 8.94 billion m^3, and the average annual decrease is 0.19 billion m^3.

The water diversion quantity from the lower Yellow River assumes in "M" shape with double peaks in a year. The first water use peak (the former peak) is from March to May, and the second (the later peak) is from Aug. to Sep. See Fig. 3.

4.2 Quantity of local ground water used

From 1991 to 2003, the annual average quantity of ground water used for irrigating in the irrigation area of the lower Yellow River is 4.37 billion m^3, among which the quantity of 2002 was the biggest, which was 5.76 billion m^3, and the quantity of 1994 was the smallest, which was 3.64 billion m^3. From 1991 to 2003, Henan Province used 2.2 billion m^3 and Shandong Province used 2.17 billion m^3, see Fig. 4.

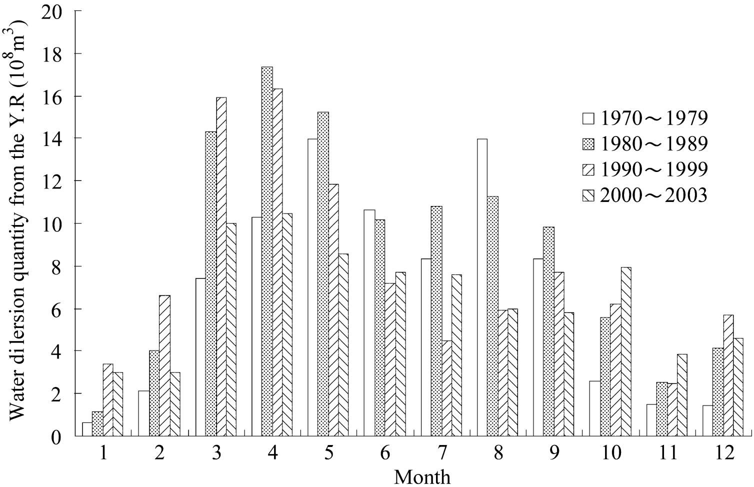

Fig. 3　Allocation of diversion water during the year

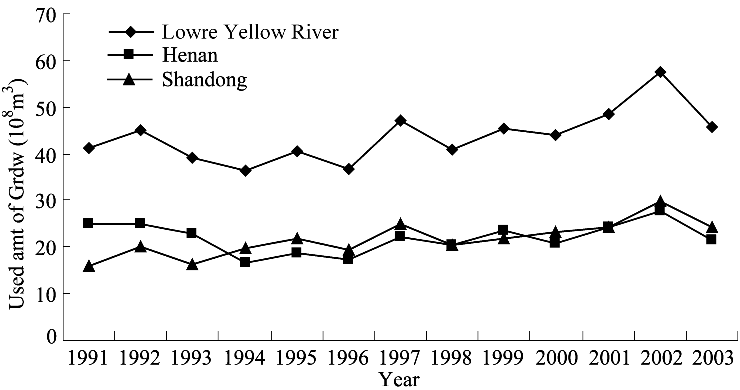

Fig. 4　Quantity of ground water used

4.3　Quantity of local surface water used

From 1991 to 2003, the annual surface water used for irrigating in the irrigation area of the Lower Yellow River was 0.82 billion m^3, among which Henan Province used 0.21 billion m^3, Shandong Province used 0.62 billion m^3. See Fig. 5.

4.4　The makeup of the water used in the irrigation area of the Lower Yellow River

From 1991 to 2003, the annual water used in the irrigation area of the Lower Yellow River is 14.4 billion m^3, in which the water diverted from the Yellow River is 9.24 billion m^3, the underground water is 4.37 billion m^3, and the local surface water is 0.82 billion m^3, occupying 63%, 31% and 6% of the total water used respectively. The diverted water and ground water primarily used by the irrigation area of Henan, occupy 46% and 50% of the total respectively, whereas, the irrigation area of Shandong used diverted water primarily, occupying 71% of the total

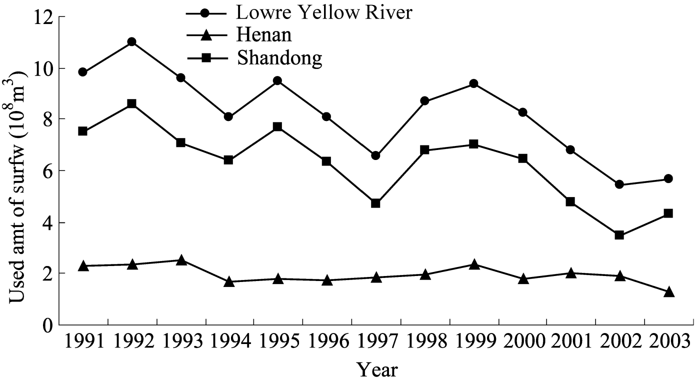

Fig. 5 Quantity of surface water used

water used, and the ground water only accounts for 23%. The proportions of the two provinces' local surface water used in the total water used are quite low, about 4% to 6%, as shown in Fig. 6.

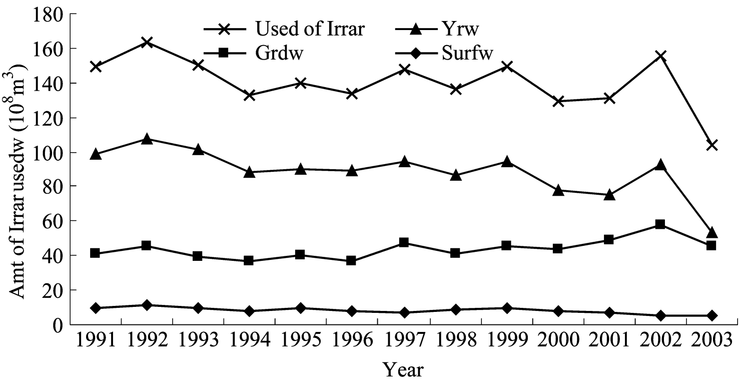

Fig. 6 Process of water used in the irrigation area

If the period from 1991 to 2003 is divided three: 1991 ~ 1995, 1996 ~ 2000 and 2000 ~ 2003, we can see that the total water use in the irrigation areas of the Lower Yellow River and Henan and Shandong assumes a slow drop tendency. The water used at the three intervals are 14.7 billion m^3, 13.9 billion m^3 and 13.0 billion m^3 respectively, among which Henan irrigation area shares 4.55 billion m^3, 4.24 billion m^3 and 4.52 billion m^3, and Shandong takes respectively 10.2 billion m^3, 9.71 billion m^3 and 8.52 billion m^3. The water consumption change of different water source presents a situation of "two low and one high": Water diversion from the Yellow River and local surface water use reduce gradually and underground water use increases gradually. The proportion of the diverted water during the three intervals in the total water use drops to 63% and 57% from 66% and the local surface water use drops to 6%, 5% from 7%, on the contrary, the underground water use rises to 31%, 39% from 27%.

5 Ideas and countermeasures to guarantee crop safety by water supply in the Lower Yellow

Irrigation is the one of most important measures to guarantee the grain production, without which other measures will be useless. The irrigation in the Lower Yellow River enjoys centuries –

old history. With the developing of economy and the growing of population, the reducing tendency of farming resources in the Lower Yellow River is hard to reverse, and the contradiction between water supply and demand is becoming more and more prominent. Under the conditions of water saving, adjustment of industrial structure, limiting industry of high water consumption, the national demand of water resources will still somewhat grow. At the same time, the water use structure will also have a sweeping change, which means that the guarantee of water supply should be correspondingly enhanced. As a matter of fact that most water is consumed in agriculture, so it needs to save water in agriculture, and to increase the water use efficiency to safeguard the water demand of food security.

According to the achievements of national science and technology project, the volume of irrigated underground water is 4.181 billion m^3 in the irrigation area of the Lower Yellow River under united irrigating condition of wells and ditches. The volume of irrigated surface water and diverted water for industrial and domestic use adopt the mean value of the recent three years. According to the above conditions we can calculate the total quantity of water at diversion sluice of the lower Yellow River that accounts for 9.311 billion m^3 as listed in Table 1.

Table 1 Water need at water diversion gates **Unit: 10^8 m^3**

Water neeed for irrigation				Industrial and domestic use of water	Total demand of water diversion
Subtotal	Ground water	Surface water	Diversion water		
130.83	41.81	5.91	82.91	10.2	93.11

From the grain production condition and the economy level of development in the Lower Yellow River, we can see that the grain production is at low level in the structure and safety, and regional food security coexists with insecurity. Facing the challenges of sterning and sterning food security situation and the water resources situation, to safeguard the downstream area's food security by the sustainable water resources' use is an urgent question needed to be solveed in lower Yellow River's water resources management.

5.1 Reinforce the water diversion management

The State Council allocated 11.7 billion m^3 to the area downstream of Huayuankou for normal year, among which Henan gets 3.13 billion m^3 and Shandong 7 billion m^3 (including Dawen River's 0.43 billion m^3) and diversion water to Tianjin at Weishan Gate 2 billion m^3. Under the present situation and the ground water mining plan condition at 75%'s guarantee rate of precipitation, the available water in the Lower Yellow River irrigation area may be possible to satisfy the Henan's present irrigation water need, rather than Shandong. After 2000, the water demand is 7.85 billion m^3, which surpasses the assigned target and the supply and demand contradiction is extremely prominent.

The water diversion has solved the problem of uneven spatial and temporal distribution of water in the Lower Yellow River's water resources, which has guaranteed the water use in the Lower Yellow River's irrigation area, and played the main role in the irrigation area's grain production. We should strengthen the real-time dispatching, reporting diversion water, waste water and moisture retention information promptly, accurately and in a standard way, and analyze the water demand and actual water diversion situation along the Yellow River, and adjust the water diversion volume in accordance with the real situation promptly. We should enhance the regulative ability to allocate water resources in time and space, providing the effective safeguard for the basin's food security and the social development.

5.2 Advance the construction of water saving society, change the provide – oriented water management to demand – oriented water management

5.2.1 Construct the water saving society

Through the construction and transformation of management system, it is to establish water resources management system on the basis of water rights and water market theory, and to form the saving water mechanism primarily through economical method, and to establish the autonomy development of water saving pattern, and to enhance the water resources' use efficiency and benefit.

5.2.2 Change the management mechanism

Because of the backwardness of technical and management level and the irrigating facility's aging, the current irrigation water use efficiency is only about 0.4, which is far from the developed country's 0.7 ~ 0.9. The crop moisture content's productivity is less than 1 kg/m^3 (0.87 kg/m^3), but Israel's is 2.32 kg/m^3. As for the field project inferior to lateral canal in the irrigation area, the power and responsibility should be put on the specific water use household association or individuals, by establishing of the water supply company plus water use association, to realize the effective management mechanism of self – control, automatic service and independent water supply of inferior branch canal.

5.2.3 Establish the reasonable forming mechanism of water price

Because the water fee is extremely low and many irrigation areas are short of funds, the maintenance depends on the diversified management and the irrigation area's management has become side occupation actually. Also there are some management authorities which instead encourage the farmers to use more water to create income because the diversified management is difficult and the water fee is very low, and the loss with management backwardness brings far too higher loss than the loss that some technical backwardness creates.

The water fee question is the key to carry out the water – saving agriculture, which relates the enhancement of all the people's water – saving consciousness, the irrigation area's transformation and maintenance and development. The water resources should be regarded as a scarce economical resources, and the water resources' optimized use should focus on the extant water resources supplies. To implement the systems of "two parts of water price" which are the basic water price and the measurement water price, progressive increase of water price beyond the quota and seasonal fluctuation water price and so on, and to urge the water use structure and the planting structure's adjustment, and to change the provide – oriented water management to supply – oriented water management.

5.3 Change single technology to comprehensive technologies

Enhancing the agricultural water use efficiency definitely cannot rely on a single or several project measures, but a set of water saving agricultural technology system. We should take technical measures of water conservation, agriculture and management to speed up the water saving transformation in the irrigation area diverting water from the Yellow River, and to support economic society's water resources demand by developing the irrigation area's agriculture water saving.

(1) In the agronomy measure aspect, we should adjust the agricultural production structure, take the water saving cultivation measures and reduce crop evapotranspiration. Use the membrane mulching and straw stalk cover, reform the land and cultivate the fertilizer. Carry on irrigation to the

crops at right moment and right amount through advanced irrigation method, adjust soil moisture to guarantee the crops synthetic request of water, fertilizer, atmosphere and heat. Promote and control the crops' growth, enhance the crop yield, and optimize the product quality to obtain the irrigation way of the best economical output.

(2) The water saving irrigation system is the foundation of highly effective use of water in agriculture. We should make full use of the precipitation, develop soil water and adjust ground water reasonably, to achieve the goal of balance in exploitation and recharge and of close union of agriculture and water measure. We should change the extensive irrigation to fine irrigation, at the right moment and right amount to carry on the scientific irrigation for maximization of the limited water resources in the region and geting the best benefit.

(3) According to the water resources conditions, we should adjust the industrial structure and the water use structure, enhance and improve the irrigation area's agricultural production condition. Make full use of natural rainfall, enlarge the infiltration quantity, enlarge the vegetation area, and reduce the ground evaporation. Through the unification management of both surface water and ground water, through the union utilization of ground water and the Yellow River water resources, we can enhance the water use efficiency.

5.4 Flood utilization

According to flood's periodical characteristic, we may raise the flood prevention limit water level of the Xiaolangdi Reservoir in Sep. and Oct. suitably (later period) to retain more flooding water in flood season, and to enhance the guarantee rate of non – flood season. Gathering more water in flood season can increase the volume of water resources adjustable for the supply to cities and for farmland irrigation, and display the reservoir's comprehensive utilization benefit.

Construct reservoirs in the plains along the Yellow River to hold extra flood water in flood season, unify the questions of more water or less water, water quantity and water quality, and divert water from the Yellow River in advance, or divert water in flood season to remedy the insufficiency of inflow from the upper reaches in spring. This is the inevitably request of the economy and social development, to retain water in winter for spring use, to retain water in abundant time for use in dry time, to divert water from the Yellow River for replenishing source, and to realize the reasonable water resources disposition.

5.5 Enhance the technical innovation capacity

Technical advancement drives grain production increase, and to guarantee the country's food security and sustainable development requests a higher need of the grain science and technology development. The development of new technology in irrigation and fine agriculture, non – full irrigation and adjust – deficient irrigation will play a vital role in increasing agriculture production by saving water. In order to protect the food security in water crisis, we must obtain new breakthroughs in science and technology.

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From Struggle to Harmonious Coexistence between Mankind and Water

—Practice of Unification Management of Yellow River Water Resources in Shandong

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Abstract: The local water resources of Shandong Province are seriously insufficient. The Yellow River is its main guest water resources. Because of the over – development and utilization, zero – flow of the Yellow River has come out for 21 years in the past 28 years from 1972 to 1999, and brought about serious influences on local industry and agriculture, drinking water, ecological environment and the flood prevention along the Yellow River. The Yellow River Conservancy Commission, authorized by the State Council, is in charge of the integrated management and regulation of the Yellow River water resources. Yellow River Shandong Bureau, as the management and responsible department of Shandong Province, has taken many kinds of measures to strengthen the unification management and regulation. As a result, zero – flow has not taken place for 8 years since 1999. The water need of local industry, agriculture, urban and rural inhabitants along the Yellow River in Shandong has been basically satisfied. Remarkable economic, social and ecological benefits have been obtained, and the harmonious coexistence between mankind and water promoted.

Key words: the Yellow River, water resources, management, practice

1 Introduction

1.1 General situation of water resources

The local water resources of Shandong Province are seriously insufficient with a total amount of 30.8 billion m^3, and 344 m^3 per person averagely which is only 13% of the national average amount. It is much lower than the lower limiting value of 1,000 m^3, which is internationally recognized to maintain sustainable socio – economic development. Shandong belongs to one of the provinces seriously lacking of water. The shortage amount in the entire province is 9.8 billion m^3 in normal years and high up to 17.5 billion m^3 in arid years. The shortage of water resources has become a restriction factor like "bottleneck" on the economic and social sustainable development in Shandong.

Shandong is situated at the most down – reach of the Yellow River. The Yellow River flows through 9 districts and 25 counties of Shandong with a river course length of 628 km. The Yellow River water resources are the most dominant guest ones for Shandong. The multi – annual – average runoff is 58 billion m^3 for the whole River, after deducting the water consumption to transport sediment and to maintain the ecology, the total volume which can be utilized in normal years is only 37 billion m^3 at most. The target for Shandong is only 7 billion m^3 which is assigned by the State Council in 1987. At present, 11 districts and 68 counties of Shandong have been able to use the Yellow River water. The Yellow River water – use amount and irrigated areas occupy approximately 40% of that in the entire province. The Yellow River water resources have been holding a pivotal strategic status for the economic and social development in Shandong.

1.2 Zero – flow situation of the Yellow River

The first natural zero – flow of the Yellow River began in 1972. Statistics have indicated that in 28 years from 1972 to 1999, zero – flow had taken place at Lijin Hydrological Station in 22 years, 89 times and 1,091 days with an annual average of 50 days. Especially in 1997, it was up to 226 days.

In 1990s, zero – flow of the Yellow River happened almost every year, and presented several characteristics below. First, the zero – flow years increased unceasingly with 6 years in 1970s, 7 years in 1980s and 9 years in 1990s. Second, the zero – flow frequency increased unceasingly with 14 times in 1970s, 15 times in 1980s and 60 times in 1990s. Third, the zero – flow time lengthened unceasingly with 86 days in total and 14 days of annual average in 1970s, 86 days and 14 days of annual average in 1970s, 107 days and 15 days of annual average in 1980s, and 898 days and 100 days of annual average in 1990s. Fourth, the first time of zero – flow came earlier and earlier in May or June in 1970s and 1980s, and February or March in 1990s. Fifth, the length of zero – flow extended unceasingly with 242 km in 1970s, 256 km in 1980s and 422 km in 1990s. Especially in 1972, it was up to 683 km approximately near Kaifeng city of Henan Province.

Zero – flow of the Lower Yellow River has brought significant economic loss for industrial and agricultural production, and has also had serious influence on domestic water of rural and urban, ecological environment and river course flood prevention. Statistics have indicated that the industry and agriculture loss in the lower Yellow River as follows: 2.22 billion yuan in 1970s in total, 2.92 billion Yuan in 1980s, and 21.64 billion yuan in 1990's (by 1996).

In 1997, the direct economic loss from zero – flow in Shandong was high up to 13.5 billion Yuan, of which industrial loss was 4 billion Yuan, agricultural loss 7 billion Yuan and other loss 2.5 billion Yuan. The drought – suffered areas along the Shandong reach amounted to more than 23 million ha., with heavy drought areas of 16 million ha. and absolutely no production of 7.5 million ha. It's difficult for 1.3 million people in 2,500 villages to get drinking water along the Shandong reach. Most of the cities along the Shandong reach had to fix water supply time and quota, and inhabitant drinking water had to be pulled by automobiles to supply some cities.

1.3 The water resources management situation before authorized regulation

The first Yellow River water – intake gate – Qijiazui gate was constructed in 1950, here after the development and utilization of the Yellow River water resources had experienced experiment, doing in a big way, stopping and duplicating irrigation, development and enhancement, zero – flow and unification dispatch and so on. Statistics have indicated that the multi – annual average water – intake amount was 4.8 billion m^3 in 1970s with an year – mean irrigated area of 11 million ha.; 7.6 billion m^3 in 1980s with an year – mean irrigated area of more than 1.3 million ha.; 7.3 billion m^3 in 1990s with an year – mean irrigated area of more than 1.7 million ha.. Especially in 1989, it was 12.3 billion m^3 and 1.8 million ha.

In 1980s, because zero – flow with less frequency and time had not too serious influence on production and life, the Yellow River management department and the local governments only adopted some temporary emergency measures to adjust the water to the downriver such as limiting upstream water – intake or closing upstream gates in a short time. Since 1990, because the situation, harm and influence was getting more and more serious, under the leadership of the Shandong Provincial government and YRCC, Yellow River Shandong Bureau (simplified by Shandong Bureau below) has taken many measures as follows to try to prevent zero – flow: Firstly, paid much attention to the Yellow River water state, drought situation and water – need of each place along the Yellow River, and report promptly them to YRCC to request the support to Shandong's drought – combat by enlarging discharge – excrete from the reservoirs in the upper and middle reaches in time. Secondly, planning water – use, assigning the water – use target, closing gates, and fetching water in turn and so on were adopted. Thirdly, put forward suggestions of constructing plain reservoirs and taking full use of reservoirs, river courses and ponds to store and regulate water, in order to utilize in dry time the water gathered in water – abundant time, utilize in spring the water gathered in winter. All these measures above alleviated the supply and demand contradictory of the Yellow River water in some time and certain degree. Because the basin water resources couldn't be yet jointly managed and dispatched, the water – use amount of the provinces in the upper and middle reaches have been increasing unceasingly, zero – flow and its harm have still been unceasingly intensifying.

2 Measures taken since authorized management and regulation

In 1990s, zero – flow was getting more and more serious, and the government and all walks of society have paid high attention on the problem. 163 academicians from Chinese Academy of Science and Academy of Engineering seriously signed to appeal the State to take measures to solve the zero – flow of the Yellow River. In December 1998, approved by the State Council, the State Planning Commission and Ministry of Water Resources issued "Yellow River Water Dispatch and Management Method". YRCC was authorized to be responsible for the Yellow River water unification dispatch and management, and Yellow River Shandong Bureau was responsible for the Yellow River water resources unification dispatch and management within the boundaries of Shandong. From March 1999, the Yellow River water unification dispatch has come into truth. Since then, Shandong Bureau has been unceasingly trying to adopt many kinds of methods such as administration, economy, law, project, technology and so on to strengthen the water resource management and dispatch. As a result, zero – flow has not come again for 8 years continuously.

2.1 Administrative method

As the water administration responsible department of Yellow River Shandong section, Shandong Bureau has been taking Yellow River water dispatch as an important task and taken many administrative measures below. Firstly, real – time dispatch. According to the Yellow River water state and drought situation, promptly issue water dispatch instruction, adjust discharge of sluices to deliver the Yellow River water to the places where are most needed. Secondly, sign letters of responsibility by all levels and carry out the responsibility system layer upon layer. Since 1999, all levels of the Yellow River administration departments including the province, the district and the county have been signing Yellow River water supply letters of responsibility, implementing the main director responsibility system, and stipulating penal terms for contrary behaviors. Thirdly, strengthen surveillance and inspection. During critical water regulation periods, send out inspection teams to carry on the surveillance and inspection task by staying at selected places, touring inspection and spot – checking suddenly and so on, and the inspection results will be noticed in the overall scope of Shandong Bureau. Fourthly, explore innovation unceasingly in plan water – use, scientific dispatch and water resources management, implement water – supply agreement system, order form water supply system, water dispatch written notice system, water – intake licensing system and water resources proof system for water – use constructions. All these measures above have obtained tangible effects.

2.2 Economical method

Collect water fee according to the national water fee standard, and exert water price – increase policy for ultra plan water according to the stipulation implementation. Because the prices of different usages are quite different, in order to save water and utilize water reasonably, Shandong Bureau has done much work to distinguish water – use limit of agriculture with non – agriculture.

2.3 Legal method

Shandong Bureau earnestly has been carrying out "Water Law", "Water – intake licensing

Act" and the rules and regulations formulated by the Ministry of Water Resources and YRCC. In the mean while, Shandong Bureau has set down many management methods as follows since 1999: "Shandong Yellow Water Supply Dispatch and Management Method", "Shandong Yellow River Water Supply Agreement System", "Shandong Yellow River Water Dispatch Responsibility System", "Shandong Yellow River Water Dispatch Supervise Means", "Shandong Yellow River Water and Sediment Measurement and Report Management Method", "Shandong Yellow River Water Dispatch Regulation" and so on. All these above have been playing a vital role in strengthening Shandong Yellow River water unification dispatch.

2.4 Engineering method

63 Yellow River water – intake sluices have been keeping good conditions of open and shut state easily etc. In order to take full use of the scarce Yellow River water resources, massive water storage and regulation projects have been constructed along the Yellow River. By the end of 2004, the Yellow River water holding capacity of the districts along Shandong Yellow River has reached 2.274 billion m^3. The number of plain reservoirs is 753 with a water holding capacity of 1.463 billion m^3. The water holding capacity of river courses and ponds is 811 million m^3. The projects above have laid a foundation on abundant gather dry use, winter gather spring use.

2.5 Technical method

First is to establish reasonable water – use plans to strengthen water – use management. Considering the water to meet with sediment – carrying and ecologic use as premise, according to crops' sown areas and water – need rule, establish scientific water – use plans and carry them out strictly. Second is to carry on foundational investigation and study. Shandong Bureau and its subordinate companies went into Yellow River irrigated areas, floodplains many times to investigate and study irrigation area, floodplains, plain reservoirs, agricultural plant structure, industrial and domestic water – use, water – saving for irrigation and so on. All these above have laid technological base for the reasonable disposition of the Yellow River water resources. Third is to raise water dispatch modernization unceasingly. In recent years, develop correlative utilization software by network technology. It's come into true to transmit and consult water level, the diversion amount of water and sediment, dispatch written notices and so on. Using advanced computers, automatic control and video – frequency transmission technology, the long – distance supervisory system of 51 sluices have been completed. Five levels of monitoring have been realized including YRCC, provincial – level, city – level, county – level bureau and sluice – manage company. The information and running status of sluices can be monitored on the long – distance, the shut and open of sluices can be controlled on the long – distance, and the movement environment and fluid state of sluices can also be monitored on the long – distance. All these have provided a powerful technical strut for the scientific dispatch.

3 Remarkable successes by the Yellow River water resources authorized management

Since the Yellow River water resources unification management and dispatch in 1999, although the water in the Yellow River has always been in bad situation, the number of zero – flow days in 1999 reduced to 40 days, from 2000 to 2007 zero – flow has not taken place for 8 years continuously. At the same time, the water – need for industrial and agricultural production, rural and urban inhabitant living has been basically satisfied along the Yellow River. Remarkable economic, social and ecological benefits have been obtained.

3.1 Industrial and domestic water – use benefits

The water – struggle between upstream and downstream or left bank and right bank was avoided because all – round factors had been considered in implementing the Yellow River water resources unification dispatch. The water supply to 6.36 millions rural and urban inhabitants has been guaranteed in the first place along the Shandong reach, and that for Shengli Oil Field and industrial production has been basically satisfied. At the same time, the water supply for 17.05 million people of Qingdao, Tianjin and the cities on the way has provided by Transfer Yellow River Water to Tianjin Project and Transfer Yellow River Water to Qingdao. The influence on industrial GDP from the Yellow River water is 211 yuan/ m^3 (Estimated by YRCC), so the annual industry GDP influence quantity by the Yellow River water resources amounts to about 120 billion yuan for the cities along the Shandong reach.

3.2 Agricultural benefits

Because the water – need rule of crops have been fully considered, in the essential water – use season of crops, the discharge capacity of Xiaolangdi Reservoir could be enlarged at the right moment, and the crops of more than 30 million ha. was basically able to obtain the prompt irrigation along the Yellow River. According to some survey, the annual production – increase benefit by Yellow River irrigation in Shandong amounts to 3 billion Yuan.

3.3 Ecological benefits

7 – annual – mean water volume at Lijin Hydrological Station, the last one of the Yellow River is 11.48 billion m^3 from 1999 ~ 2005, which has guaranteed the basic ecological environment water – need. As a result, ecological environment at the mouth area of the Yellow River has improved remarkably such as the obvious increase of fresh water wetland area, the restoration of wetland function in some certain degree, nearly millions of birds coming here to survive the winter every year. No zero – flow of the Yellow River has created suitable conditions for the near – sea fishes' migration, multiplication and living. Long – tailed anchovy not to be seen for many years has reappeared in the Yellow River course again.

In recent years, the trees on both banks of Shandong reach are becoming more and more, water surface is gradually expanding, and ecological environment is showing a distinct improvement. Especially the springs of Spring City – Jinan can well up all the year round. Dongchang lake in the water city of north Changjiang River – Liaocheng waves ripple. Water is blue and sky is blue by the new city – round river and five lakes around Binzhou city. Fish leaps and birds fly at the mouth of the Yellow River. All these above have become new tour spots in Shandong and good entertainment places for inhabitants there profiting from the Yellow River water supply and supplement.

3.4 Flood prevention benefits

No zero – flow means that there will be some water all the year round to carry silt into the Bohai Sea, which has played a vital role in reducing the silting – up of river course, added by water and sediment regulation in these four years. As a result, the beach – even current capacity in the main channel of Shandong river course has promoted from about 2,000 m^3/s to 3,500 m^3/s, and the water level with the same current capacity of 3,000 m^3/s has dropped by 0.86 m. The ability to expel flood has a universal enhancement for the river course of the Shandong section.

4 Existing problems and countermeasures

The Yellow River water resources unification management and dispatch has brought about huge economic, social and ecological benefits for the areas along the Shandong reach, but some existing problems of Shandong Yellow River water resources management and the dispatch are waiting urgently to be solved.

4.1 The total quantity of water resources is insufficient

Frequent zero – flow as the symbol means that the utilization of the Yellow River water resources has already surpassed the river's bearing capacity limit. Before the implementation of South – to – North Water Transfer Project, the supply and demand contradictory of Shandong Yellow River water resources will be still extremely prominent, especially in the spring. This is because water – use for irrigation in spring approximately composes about 60% of the water consumption of a whole year, but the water to enter Shandong at the same time only accounts for about 20% of the whole year. It will be quite difficult to change completely the water – shortage situation in a short – term in Shandong. Countermeasures: Implement Water Transfer West Line Project from South to North as soon as possible to solve the problem that the total quantity of the Yellow River water resources is insufficient fundamentally. Enlarge the current discharge capacity from Xiaolangdi Reservoir and so on to alleviate the contradictory of water supply and demand in the spring irrigation period.

4.2 Legal method is unsuitable

The laws, acts, rules and regulations for unification management and dispatch of the Yellow River water resources are still not perfect at present. Countermeasure: Suggest the State to issue relative laws and regulations as soon as possible such as "the Yellow River Law" and so on to bring the Yellow River water resources management and dispatch into the track to manage by laws.

4.3 The method of hydrological measure and report is dropped behind

First is that there are less hydrological stations, lower measure precision and fewer measure frequency in the main stream of the Yellow River, which cannot meet with the water dispatch need. Second is that there is less discharge – measure frequency and larger measure error for sluices' flow gauging. Third is that water monitoring, water measuring and water allocation are too draggled to meet the water regulating request in the Yellow River irrigation areas. Countermeasures: First is to improve the measuring equipments of Yellow River hydrological stations and increase the number of measuring and reporting. Second is to transform flow – measure facilities of sluices to realize the flow – measured modernization as soon as possible. Third is to increase measure – stands and enhance the precision of measure and report to adapt the water – matched need combined with the transformation of irrigation areas.

4.4 The management level of irrigation areas is lower, and the waste of water resources is

First is that the projects of irrigation areas can't match each other, and abstention gates in the main channels and branches are in bad repair sometimes. There are 17,390 kilometers of main channels and branches in all in Shandong irrigation areas, 1,315 kilometers of which is lined, and the lining rate is only 7.56%. Water utilization coefficient is only about 0.5 with flood irrigation and string – irrigation mostly. Second is that there is not water – use rations by now. Third is that the management of irrigation area project is not unified, so there are struggles for water between upstream and downstream, and the use of groundwater is unreasonable. Countermeasures: First is to match the irrigation area projects, especially the lining work of main channels to enhance water – use coefficient. Second is to jointly regulate the surface and underground water in irrigation area and the Yellow River water. Third is to set down scientifically each kind of water – use rations to promote water – saving and water – allocation.

4.5 The water fee price is too low to exert effectively economical release lever control' action

First is the Yellow River water – supply price at head works is too low with a standard of 0.01

yuan/m^3 for irrigation water, and 0.04 yuan/m^3 for no－agricultural water. Second is the water－supply price at irrigated areas is also too low with a standard of about 0.051 yuan/m^3 for irrigation water. All above are lower by far than the water supply cost. Countermeasures: Suggest concerned departments according to the rules to check and ratify the water fee price for head works and irrigation areas as soon as possible, exert plan－ultra water to implement progressive price, carry out two－step system water price gradually, and fully bring water price into play in the water resources management and regulation of the Yellow River.

5 Conclusions

To sum up, Shandong Province cannot live without the Yellow River. Great achievements have obtained through the unification management and regulation in recent years. But it will still have a long way to go to realize the harmonious coexistence between mankind and water. The Yellow River management department, all levels of the governments and stakeholders need together to try hard to take integrated methods such as law, administration, economy, technology, project and so on to strengthen the water resource management and dispatch to promote the reality of the harmonious coexistence between mankind and water, and the sustainable development of economy and society along the Yellow River.

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Rational Water Resources Allocation in the Northwest Arid and Sandy Areas:

—The Case Study of Yan'an City of China

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Abstract: In the paper, the author takes the Yan'an city as a case, which is the representative areas of the northwest arid and sandy areas in China, analyses the comprehensive effects on regional water resources, which caused by the changes of precipitation, the structure of social water use and soil and water conservation. On the basis of these, the water resources in Yan'an city is rationally allocated, as the results are shown in this article. The author builds the rational water resources allocation model for Yan'an city, also, the author analyses the effects on the results of allocation, which from the change of climate, water and soil conservation and the structure of social water use. The effects analysis includes the qualitative analysis and quantificational calculation. We find that the trend of precipitation is descending, but it's difficult to quantify the effect from the change of the global climate and the alternation between the flood and dry period. And under the evolutional scenario of ecosystem, the flow in the river will be fluctuated less acutely, became evenly, it does good to utility water resources efficiently. The downstream water allocation is strongly influenced by the ways of human get and use water on the upstream, because the drainage of upstream will pollute the water flow to downstream. At last, the author puts forward some proposals for rational water resources allocation, and discusses the issues for the future water resources allocation.

Key words: water resources, rational allocation, the arid and sandy area, state evolvement

1 Background

In the northwest of China, there are some regions where the soil erosion modulus is high which caused by rainstorm, and so the proportion of sand and water is also high. In this region, the annual average volume of water resources is 163.5 billion m^3, accounting for 5.48 percent of the volume of the whole county. And the average water resources amount per capita is somewhat less, for example 1,781 m^3 in the year 2000. Even though it's very scarcity for water resources in northwest of China, the efficiency of using water is still low. There are many problems, such as the average water use amount per capita is high, the irrigation ratio is high, the average water use amount for per GDP is high, and the development level of water resources is increasing, up to 53.3%, but the mean value of the whole county is 20%. These problems have blocked the development of this area.

The city of Yan'an is lies in the middle east of the Loess Plateau in the middle of the Yellow River, it is the typical arid and sandy area in northwest of China. There are five rivers in this region, which are all flowing system of the Yellow River. The characteristics of these rivers in this region is that the rivers generally flows from northwest to southeast, the base flow is small, but the volume of water resources is very large with high the sediment concentration and sediment load during flood period, which makes them as a main source of sand for the mainstream of the Yellow River. According to the results of water resources assessment, the total amount of water resources is 1.335 billion m^3 in Yan'an, the average water resources amount per capita is less than 700 m^3. The average water use amount per capita is about 78.2 m^3 per year, only amounts for 17.5% of that of the whole country. In year 2000, the total water use amount of Yan'an is only 0.16 billion m^3, and accounts 11.2% of the total water resources of the region, although the level of water use and water resources development level are both low, it still suffered from water shortage problem due to the following reason: ①The precipitation is uneven during a year in Yan'an city, the volume of precipitation accounts for 70.8 percent during the period from June to September; ②The water quality of some rivers is bad; ③The human activities lead to high sand concentration of water. Therefore, it's essential for this region to do the rational water resources allocation, and it's key to sustainable development for regional water resources system.

2 The Trend of water resources evolution

The water resources of Yan'an come mainly from precipitation, so the magnitude and trend of precipitation is decisive factor to regional water resources. Human activities have important influence to regional water cycle process and erosion modulus, because the social economic water use formed the human lateral hydrologic cycle, such as the water drawing, delivery, use, drainage, treatment and reuse. Also the activities of soil and water conservation to prevent soil erosion coexist with the increscent soil erosion, which are both influencing the regional runoff.

2.1 The trend of precipitation

The change of global water cycle caused by climate change and global warming has also brought a series of influences to local rainfall runoff of Yan'an. As shown in Table 1 and Fig. 1, the annual precipitation has generally presented a decreasing trend of in last 40 years although, there are some fluctuation from 1960s to 1990s, the precipitation is rich during 1960s, it's relatively decreased during 1970s except slightly increase in some stations, but it's fell to the lowest level in recent 40 years during 1990s.

Table 1 Some river and station's annual precipitation of different years Unit: mm

Classify	Name	1960s	1970s	1980s	1990s	Average
Station	DanBa	585.8	474.4	456.9	310.2	461.7
	FuChun	621.2	517.3	546.1	533.3	555.9
	ShangZhenZi	574.9	535	553.5	508.4	548.2
	ZiChang	534.4	511.6	503.9	423.1	493.7
	JieZiBian	624.5	563.7	556.4	441	554.2
River	QingJian River	510.3	489.5	474.2	434.2	457.9
	Yan River	558.1	497.2	537.5	429.1	504.6
	Luo River	578.51	542.04	533.52	417.6	483.2

2.2 The influences of social economic water use

The water resources development activities have changed the characteristic of runoff yield and confluence of surface water and the characteristic of replenishment and drainage of groundwater, and so, the relation between runoff and precipitation, the relation between river and lake, the depositing environment of groundwater, as well as the transform route between surface and ground water. And at the same time, the human lateral hydrologic cycle come to birth in the natural water cycle frame, which includes the water drawing, delivery, use, drainage, treatment and reuse.

Along with the rapidly development of social economic of Yan'an, the water use is also experiencing a rapidly increasing process. The volume of water use has increased from 66.98

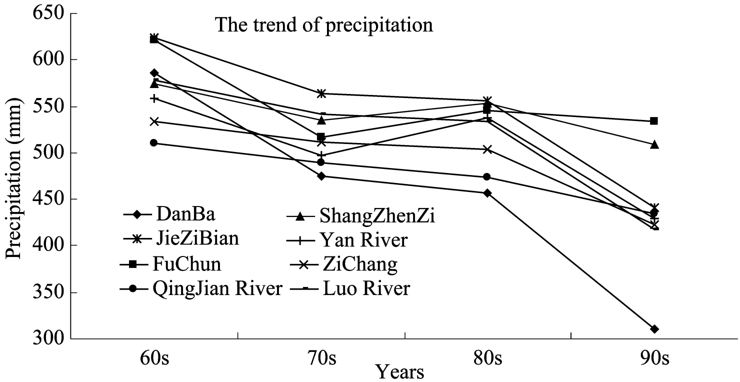

Fig. 1 The trend of annual precipitation of each age in different river or single station

million m^3 in 1980 to 160. 71 million m^3 in 2000, which is nearly 2. 4 times of that of 1980. According to recently development condition of Yan'an City, the total amount of water use is accounting for about percent 11. 2 of the total water resources, but the extent of water use will be further increasing, and the water use of Yan'an City is largely depend on river water, so the surface runoff of drought period will be greatly influenced. And there is consumption and regeneration water in the social economic water use process, combined with drawing, delivery and drainage process to form the human lateral hydrologic cycle, augment the complexity of the process of cycle.

The water cycle is changed by the human lateral hydrologic cycle. It's mainly changed the mechanism of natural runoff yield and confluence. During the water resources development process, water is mainly consumed in the water use process, which leaves the surface system in the form of component of products and evaporation. The drainage and treated water will return to nature, the original confluence process has been changed.

It is projected in three different standard years (2010, 2020 and 2030), the average annual water demand will up to 230. 58 million, 272. 02 million and 319. 16 million m^3, and the development rate of water resources will up to 18. 8%, 29. 0% and 37. 0% respectively. Therefore, along with the increasing volume of social economic water use in the planning year, the influence to runoff of river way will become more and more clearly.

2.3 The change of runoff caused by soil and water conservation

Soil erosion is the uppermost eco – environmental problem in Yan'an city, so soil and water conservation is the main measure for the eco – environmental construction. Just because of this, the implement of planned of soil and water conservation project in Yan'an city will bring significant benefit of ecology, economic and social. The principle measures for soil and water conservation are engineering, biological and agriculture cultivating methods. The engineering method includes sediment trap dams, terracing of sloping field and small types of soil and water conservation engineering. The biological method is to adapt some technical measures, such as afforestation, forest reserve, and so on. The agriculture cultivating method includes changing the landform of the slope surface, increasing the roughness of ground and the plant coverage, and so on.

After the implementation of soil and water conservation plan, it will prevent soil erosion, decrease the sediment yield. And hold water, delay the peak of flood period and increase the volume of water in drought period, so decrease the loss. And also prevent non – point source pollution, and improve the quality of surface water. Therefore, the measures of soil and water conservation are benefit to the development of water resources. It is estimated that by the end of 2010, the planned measures will intercept and store runoff 155. 19 million m^3, keep soil 42. 21

million ton. During the period from 2011 to 2020, the planned measures will intercept and store runoff 337.907,4 million m^3, keep soil 91.713,3 million ton. During the period from 2021 to 2030, the planned measures will intercept and store runoff 342.958,8 million m^3, keep soil 93.242,1 million ton. However, because soil and water conservation comprehensive measures consume water, the runoff amount will be decreased, and the total amount water resources will decrease in the region.

As statement above, soil and water conservation change the original condition of underlying surface, and so does the runoff yield and confluence process. This is because of the forest coverage, the improvement of eco – environment, the increase of interception by precipitation, the process of confluence delayed, the plant evapotanspiration is enhanced. And then, the river runoff is decreased.

3 Water allocation scenarios analysis

The regional water resources allocation is to harmonize the relation of using water between the eco – environment and the social economic system, and the relation among each system, to realize the sustainable development of social economic and keep the eco – environment in good condition. So, the key content of water resources allocation in Yan'an city can summarize to three points, ①The regional development pattern of social economic development, it mainly indicates to take regional water resources allocation as a ligament, the mode of harmonization among social equal, economic development and eco – environment protection. ②In each pattern, to analysis the main indices of regional social economic and eco – environment limit under the support of water resources which is macro scarcity. ③The effective mode for regional water resources allocation under the designated development mode and defined condition of water resources.

3.1 The model of water resources allocation

Short of water resources is the major problem of Yan'an city, the water demand is always exceeding the water supply in each calculation unit. In order to embody the principles of water resources allocation and the characteristics of water resources of Yan'an city, in this research the author selects to minimize comprehensive water deficiency of each river and the rate of water deficiency between every two calculation units is equilibrium as the two objects.

Object Function Ⅰ: To minimize comprehensive water deficiency

$$\min Z = \sum_{i=1}^{I}\sum_{j=1}^{12}\sum_{k=1}^{4} S(i,j,k) \tag{1}$$

where, $S(i,j,k)$ is the amount of water deficiency of the k th water use type of the i th calculation unit at j th time period.

Object Function Ⅱ: The rate of water deficiency between every two calculation units is equilibrium

$$|\max\eta_i - \min\eta_i| \leqslant \varepsilon$$
$$\max\eta_i = \max(\eta wd_{ijy} \quad i = 1,2,\cdots,I) \qquad \min\eta_i = \min(\eta wd_{ijy} \quad i = 1,2,\cdots,I) \tag{2}$$
$$\eta wd_{ijy} = \frac{\sum_{k}^{4} S(i,j,k,y)}{\sum_{k}^{4} D(i,j,k,y)}$$

where, ηwd_{ijy} is the rate of water deficiency of the y th year of the i th calculation unit at j th time period, $S(i,j,k,y)$ is the amount of water deficiency of the k th water use type of the i th calculation unit at j th time period in the y th year, $D(i,j,k,y)$ is the amount of water demand of the k th water use type of the i th calculation unit at j th time period in the y th year, ε is given value(>0).

The constraint conditions of model include: ① water balance, ② reservoir volume, ③ local natural inflow, ④the capacity of water transfer and pumping, ⑤groundwater use, ⑥ water quality, ⑦ operation rules of reservoirs, ⑧ each variable is positive.

3.2 Analysis of the result of water resources allocation

The major problem of water resources in Yan'an city is shortage, the water demand always overruns the water supply in each calculation unit. In order to embody the principles of rational allocation and the real characteristics of water resources in Yan'an city, it is the least of comprehensive water shortage and the rate among each calculation unit is equilibrium that are selected as the water allocation objectives. According to the traditional theory of three times of supply – demand balance, we need to set the allocation option under the consideration of the relevant condition of the regional social economic development. Namely, it adapts the water demand after considering water saving at the first time of supply – demand balance, the amount of water shortage will indicate the problems of supply – demand balance in the development process.

Considering the demand of the healthy social economic development in Yan'an city, the overall layout and integrated planning has been done, to ensure the water use in high rate, make the water – deficiency rate is the lowest under the definite capitalized cost for water conservancy. In recent standard year (2010), considering the potential of local water resource, it needs to increase the utilization factor of water resources and water productivity of per unit, develop the engineering of water reuse. In the middle standard year (2020), in reference to the fact of Yan'an, it needs to continuously increase the rate of renovated water utilization, if the local water source is deficiency and the potential is not enough, then it should consider the engineering of water transfer. In the long – dated standard year (2030), it needs to support the rapidly development of social economic in Yan'an city by maintenance for the engineering, reinforcement, and combined with some new engineering. The supply – demand balance results of the recommendatory option is shown in Table 2. It shows that the regional amount of water shortage in present situation is 26.5 million m^3, the ratio of water deficiency is percent 15.8. In recent standard year (2010), the regional amount of water shortage in present situation is 21.0 million m^3, the ratio of water deficiency is percent 9.1. In the middle standard year (2020), the regional amount of water shortage in present situation is 9.2 million m^3, the ratio of water deficiency is percent 3.4. In the long – dated standard year (2030), the regional amount of water shortage in present situation is 8.3 million m^3, the ratio of water deficiency is 2.6 percent. The change of the ratio of water deficiency in different standard year, the series of measures for the rational water resources allocation and increasing the ratio of water utilization is in function.

Table 2 The annual average results of supply – demand balance by a long series data of different stanrdard year of Yan'an City (Unit: million m^3, %)

Standard year	Total water demand	Total water supply	Amount of water shortage					Ratio of water deficiency				
			Agri	Agri live	City live	Indu	Gross	Agri	Agri live	City live	Indu	Comprehensive
2000	162.5	136.0	19.0	1.78	0.99	4.7	26.5	23.2	9.6	7.3	8.8	15.8
2010	230.6	209.6	8.9	0.83	1.37	9.9	21.0	13.4	4.8	5	8	9.1
2020	272.0	262.9	7.0	0	0	2.2	9.2	9.7	0	0	1.5	3.4
2030	319.2	310.9	5.8	0	0	2.5	8.3	7.4	0	0	1.5	2.6

Note: The water use of artificial ecosystem and base flow of river is relatively small, subtract it at the begin of allocation. The total amount of water demand not includes the water use by the natural ecosystem.

Therefore, on the basis of comprehensive consider the trend of water resources evolution, we can get the conclusion whether the regional industrial frame is rational, and how to regulate it according to the water resources condition by supply – demand balance analysis. The water demand results of recommendatory option in the Table 2 are obtained after regulating the industrial frame.

So, the other results in the table are the results of supply – demand balance of the recommendatory option.

4 Comments to the water resources allocation results

The results of water resources allocation is the results of supply – demand balance analysis, under consideration of the implementation of the hydro project planning, the water resources protection planning and the soil and water conservation planning. From the analysis of the calculation results, it can elicit that the trend of evolution has three kinds of effect on the results of water resources allocation.

Firstly, the trend of precipitation is decreasing under the influences of the global climate, it presents in Yan'an city is the precipitation is overall decreasing from 50s to 90s. Because of precipitation is decreasing, even though at the origin discharge modulus, the river runoff will be decreased. It's worsen the tense condition of water use, and it requests to increase the water use efficiency and the output effects of per unit water. And also, on the basis of the rules of "3E" (efficiency, equity, economy), it should develop the alternative new water sources, allocate the water resources rationally. Based on the analysis of the series of precipitation, the overall trend of precipitation from 60s to 90s of the last century is decreasing, the range vary from 11% to 47%. Also, the utilizable water resources is going down. But, at present, it cann't elicit the quantitative impact from the change of global impact and from the seasonal change between high flow period and the drought period.

In this planning, without considering the water demand of natural ecosystem, thinking the present ground vegetation coverage should keep unchanged, namely, the relation between precipitation and runoff wouldn't change. So, while considering the benefits of soil and water conservation, it's only to consider the benefits of water and sediment reduction from the fresh area. According to the planning area of soil and water conservation, and the vary measures of water and sediment reduction, the water use of ecosystem for soil and water conservation in this mode of ecosystem evolution at the three standard year (2010, 2020, 2030) is 232, 443, 460 million m^3, respectively. The river runoff will decrease after soil and water conservation, but it's more convenient for water resources development and utilization, the sediment concentration becomes low, the inflow becomes flatness, the characteristic of seasonal fluctuate acutely is being changed, it's benefit for water drawing in drought season, ensuring water resources being allocated rationally, and achieving the least ratio of water deficiency.

In the water use of artificial, include water use for live, industry, agriculture and artificial ecosystem. The main water source for supplying is water storage, water diversion, water – lifting, spring, well, vault, reclaimed water and water diversion from other area. The different water source and the way of water drawing have changed the condition of the origin water yield, affected constitutes of the amount of water resources. Also, it has changed the dissipation mode of water resources, a part of water go back to nature, a part of water is bring away as virtual water with the product, and the other part water is consumed in the process of production or water use. Based on the results of rational water resources allocation, it shows that the water flow of the control section is obviously less than the natural river runoff. Take Yan'an as a case, the outlet flow of control sections between districts are decline, the volume is equal to the water draw by the calculation unit, the Ansai, Zhidan, Baotaqu and Yanchang control sections on the Yanhe river are decreasing 10.1, 2.9, 21.3, 7.1 million m^3, respectively. And also, the condition of water consuming and drainage of upstream is directly affecting the quantity and quality allocation of water resources at downstream.

5 Conclusions and discussions

(1) The rational water resources allocation research in arid area should know the process of eco – hydrological, which need to identify the effects to ecosystem allocation, structure and dynamic by the process, and the water sources for plant growing Therefore, This approach is helpful to

understand the hydrological evolution trend after implementing of measures for soil and water conservation and water resources protection.

(2) The soil and water conservation condition and its development plan must be fully taken in account in order to obtain a rational water resources allocation in arid area. The measures for soil and water conservation has changed the condition of underlying surface, increased the water use of natural ecosystem, and decreased the river runoff. Therefore, in different planning of water and soil conservation, the effects of water and soil reduction are different in different standard year.

(3) In this paper, primary analysis and quantitative result of the influence factors of water resources evolution to the results of allocation have been presented. However, the range and sensitive analysis of the quantitative result at defined scale needs further study. Especially, it's important to quantify the effects from the changes of global climate and the changes of wet and dry year to the water resources evolution.

(4) To analyze the results of allocation, it's found that the problems in small scale supply – demand can not necessarily be correctly expressed in the large scale of allocation (calculation unit). Therefore, it is important to select a proper calculation scale for a designated region in order to achieve a good allocation result in the future.

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The Cause of Beijiang River Water Surface Curve's Descent and Evaluation of its Effects on Diversion Environment along the River

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Abstract: In recent years, the Beijiang River's bed has been undergoing severe downcutting, which resulted in drop of the river's water surface curve and caused to the diversion structures and their channels a series of new problems, such as severer scour of banks and hidden troubles in the diversion structures, threatening the dyke safety; reduced diversion volume, silting of channels in the lower reaches, poorer self-cleaning capacity of channels, worsening of water quality and great increase in the expense for water treatment. These problems constitute a great threat to the sustainable development of Beijiang regional economy. This paper describes the bed downcutting of the river, analyzes the bad effect of the bed downcutting on the diversion environment, and presents suggestions on corresponding countermeasures.

Key words: Beijiang River, river bed downcutting, diversion environment, countermeasures

1 Introduction

On June 24, Makou Station and Sanshui Station of Foshan on the Beijiang River encountered an one-hundred-year extraordinary flood event. Thanks to the people's combat, the flood peak passed through the city smoothly and the river's dykes within Sanshui were kept safe, a success was won in flood fighting. During the flood fighting, an issue set people thinking: the peak discharge of 2005 flood was obviously larger than that of 1998 flood, why was the flood stage along the river much lower than that of 1998 flood. The phenomenon indicated that river's bed was cut down severely. The severe downcutting of the river's bed resulted in lowering of the river's water surface curve at equal flow, and caused to the diversion structures along the banks and their channels a series of problems, which mainly include: sharpening of bank scour, occurrence of hidden troubles in diversion structures, threatening the safety of the dykes; reduction of diversion volume, silting of channels in lower reaches, dropping of self-cleaning capacity of the channels and deterioration of water quality; great increase in expense for water treatment. These problems, if not solved properly, will directly affect the sustainable development of Beijiang regional economy; besides, the polluted water in the diversion area will be discharged to the lower reaches, causing secondary pollution, forming chain effect. Therefore, it is urgent to deal with the problem with effective measures.

2 Analysis of Bed Downcutting Degree of Beijiang River

2.1 Analysis of Observed Data of River Bed Cross Sections and Dykes of Beijiang River

According to the observed data of the 19 large bed cross sections of the Beijiang River, since 1990, the river bed has been cut down 5 ~ 6 m, and at North No. 17 and No. 19 cross sections where the downcutting is the severest, the maximum downcutting depth amounts to 10 m and 11.7

m respectively. It can be seen from the annual change that the annual downcutting at the 19 cross sections range from 0.5 ~ 2.0 m, and is getting faster and faster1. At the end of 1996, a survey of dyke foot scour was carried out for the dyke between stakes 33 + 900 and 34 + 325, and the comparison of the measurement result with that of June 1994 showed that river bed near the dyke foot had been generally cut down 2 ~ 3 m, with maximum of 4 m, the originally gentle dyke foot became steep, and the mainstream of the river swung from the middle of the river bed to the foot of the left dyke, severely threatening the safety of the dyke. In September 1998, the river bed between the South – west stakes 51 + 506 and 52 + 080 was surveyed, and the comparison of the survey result with that of 1994 showed that the river bed of the reach had been cut down 4 m on average, and the elevation of the river bed was – 14 m. In March 1999, reinforcement was done for the dykes of this reach. In February 2000, this reach was measured again, and the result showed that the river bed had been cut down 2 ~ 3 m compared to March 1999, and the stone dyke slope became steeper. The management unit had to do reinforcement once again.

2.2 Analysis of water stages at sluice gates along beijiang river during low water period

Changes of water stages at sluice gates along the Beijiang River during low water period can reflect the general downcutting situation of the river's bed on the one hand, and on the other hand, they can reflect the degree of the effect of the river's bed downcutting on the local elevation at the sluice inlets. This paper selects two representative sluice gates – Liuzhai Sluice Gate and Huangtang Sluice Gate – for analysis of water stages at sluice gates during low water period. Fig. 1 and Fig. 2 show the monthly change of water stage during low water period at Liuzhai and Huangtang Sluice Gates respectively. It can be seen from the figs. That, from 2001 to 2004, the monthly average water stage at the two sluice gates during low water period was decreasing. According to the observed data, before 2000, the 75% design guarantee stage of Liuzhai Sluice was 2.09 m, and the mean annual stage in low water months was 1.90 m, while from 2001 to 2004, the mean stage during low water months at Liuzhai Sluice Gate was 0.77 m, 1.13 m lower than that before 2000; before 2000, the 75% design guarantee stage of Huangtang Sluice was 1.69 m, and the mean annual stage in low water months was 1.31 m, while from 2001 to 2004, the mean stage during low water months at Huangtang Sluice Gate was 0.35 m, 0.96 m lower than that before 2000.

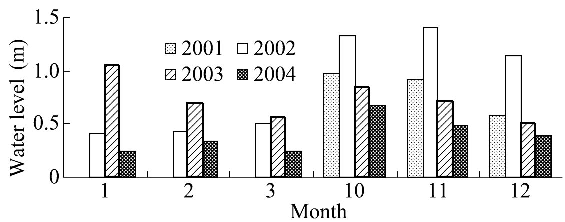

Fig. 1 Change of monthly average water stage at Liuzhai Sluice during low water period from 2001 to 2004

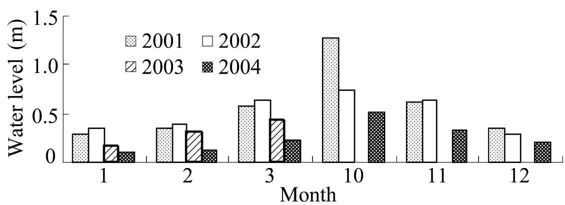

Fig. 2 Change of monthly average water stage at Huangtang Sluice during low water period from 2001 to 2004

3 Evaluation of Effects of River Bed Downcutting on Diversion Environment

3.1 Threatening severely the safety of diversion structures so that they need to be reinforced, rebuilt or relocated

Lowering of the water surface curve of the Beijiang River and the worsening of the bank scour will threaten the safety of diversion structures, therefore, these structures should be reinforced, rebuilt or relocated. Since these structures all go through the high dyke body of the river, reinforcement, rebuilding or relocation will surely involve great expense3. The diversion stage and diversion depth lower and the diversion decreases, the flow velocity becomes lower, and when it decreases to the non – silting velocity, the channel will surely be silted. To conveys the water to the lower reaches, it is necessary to dredge the river bed, or gravity flow diversion is impossible, which require large expense for the Peal River Delta, which is densely covered with rivers. Take Leping Township of Sanshui District, where 262.9 km of river channels have been cut, of which 62.34 km are main channels, according to the experiential data of desilting in the area, calculated at 500 thousand yuan per km, desilting alone will require 131.45 million yuan, furthermore, desilting must be done once every several years, which will impose a great burden on the local economy.

3.2 Diversion volume secreases, increasing expense of industrial and agricultural water use in the lower reaches

Table 1 shows elevations of sluice sills of the inner rivers and stage of the outer river during low water period of the Beijiang River. It can be seen from the table that, during the low water period, stage at all sluices was very low, even making it impossible to divert water, and the diversion volume of the sluices was much lower than the design diversion volume.

Table 1 Comparison between elevation of sluice sills and stages of the outer river during low water period

River System	Damian	Liuzhai	Left bank	Qiaobei	Datang
Sluice	Shijitou	Liuzhai	Huangtang	Wudinggang	haizikou
Low Water Stage of Outer River	0.4	0.86	0.49	0.3	0.1
Monthly Average Lowest Stage	–0.3	–0.23	–0.2	–0.4	–0.4
Elevation of Sluice Sill	–0.35	–0.1	–1.0	–1.0	1.4

Now we estimate the increment of water diversion expense caused by the lowering of diversion stage, with Huangtang Sluice as the example.

(1) Basic data

The Huangtang diver has two bores, its total breadth is 4 meter, the bottom altitude of Huangtang diver is –0.35 meter, the average of many years of water level of diver during the low water period is 1.31 meter, now it is 0.35 meter. The Huangtang diver had been made use of deficiently, calculating it as the breadth crest the weir flow.

(2) Discharge formula

Discharge formula of the breadth crest the embankment flow is as fllows,

$$Q = \sigma \varepsilon m B \sqrt{2g} H_0^{3/2} \tag{1}$$

in this formula, H_0 is head of water, $H_0 = H + V_0{}^2/2g$ (m), B is the breadth weir, σ is the submerge coefficient, the value of σ depend on the ratio between the submerge height and head of water h_s/H_0; ε is the side constriction coefficient, calculating it using the formula(2),

$$\varepsilon = 1 - 0.2[\xi_k + (n-1)\xi_0]H_0/nb \tag{2}$$

in this formula, ξ_k is the border frusta form coefficient, ξ_0 is the frusta form coefficient, m is the discharge coefficient, m is differ in form of front edge

Straight bank:

$$m = 0.33 + 0.01 \frac{3 - P/H}{0.46 + 0.75P/H} \tag{3}$$

Round bank:

$$m = 0.36 + 0.01 \frac{3 - P/H}{1.2 + 1.5P/H} \tag{4}$$

(3) Analysis of calculating result

Table 2 is calculating result, by analyzing it, the water head reduces 0.2 meter each time, the discharge reduces about the 0.9 m^3/s. From October to March is a little rainfall season, it is exact time that the abstraction water is requested mightiness, number of days of abstraction water account with 180 days during the low water period each year, difference of water head is 0.96 meter, the abstraction volume reduce 483,800 m^3 each day, the abstraction volume adds up to reduce 87,091,200 m^3 during the low water period, using 1,400 ZLB5.5 - 3.5 water pump, pump water cost 0.007 yuan/m^3, the expenses is total 610,000 yuan RMB during the low water period, there are thousands irrigation structures along Beijiang River, so this expenses is very expensive.

Table 2 The calculating of discharge under different water level of Beijiang River

Water level of river	H(m)					
	1.31	1	0.8	0.6	0.4	0.35
Water deep of diver front(m)	1.86	1.35	1.15	0.95	0.75	0.55
Q(m^3/s)	7.5	5.6	4.7	3.8	2.7	1.9

3.3 The clean power of water body descended, the water pollution turned worse, the water quality turned worse

Because the abstraction volume became low, the clean power of water body descended in the lower emerge path, the water body enriches nourishment to turn severity, the water pollution turned worse, the water quality turned worse, some water of emerge path can't used for the irrigation and marine products farming, some emerge path not only abstracted from the outside river hardly, but also exhausted the dirty water to outside river. The target of the construction of water program is as follows in The Pearl River valley, the direct management of water resources should be strengthened in the keystone region, the exasperate trend of water pollution should be suppressed in the downstream of the Pearl River. For realizing this target, water environment of the downstream of diver should be harnessed, the environmental protection expenses should be plunged into increasingly. Keeping the Huangtang diver as an example again, each kind of population of this town is about 10 myriad peoples, the standard of the living dirty water is 220 L/person/day, so it produces 8,030,000 ton dirty water every year, suppose all these dirty water demands to carry on dirty water processing because of losing the clean power of water body in the emerge path, circulate fee should be accountted with 0.6 yuan/ton, then about 4,820,000 yuan RMB processing fee was needed annually. According to above data, annually environmental protection and cure dirty expenses are very huge in the abstraction region, on one hand, an economic pressure of region increased, on the other hand, the economy development along the river was threatened enormously.

4 Suggestion of garness measures

4.1 Strengthening adjustment of reservoir of upper stream, keeping the coming amount of sediment of upper stream

The Feilaixia reservoir constructed in the upper stream of Beijiang River, it was hard to avoid to silt up with sediment. For keeping the coming amount of sediment of upper stream, maintaining the normal river sand mine of downstream, making the river bed to attain normal equilibrium, department concerned should study and draw up the reasonable method of adjustment of the Feilaixia reservoir to add the decrease of the downstream river sediment.

4.2 Strengthening the executing the law of water administration in the river valley, controlling sand mine from river bed effectively, preventing the further cut of river

①A troop of executing the law should be constructed, its organization is tight, its discipline is strict and clear, its operation is pithiness, its relation is harmony. Strengthening the executing the law of water administration in the river valley, controlling sand mine from river bed effectively, preventing the further cut of river, avoiding water surface curve of Beijiang River to descend further. ②According to the river valley program, the function area of the water body should be divided, the total dirty water amount and the water quality of cross section should be controlled. the system of admitting dirty water to river should be established, monitoring system of the water quality of cross section should be established, official gazetting system of the water quality should be established, the important water pollution affairs pursuing system should be established, the water resources of river valley should be protected effectively.

4.3 The safety of irrigation structures and the variety of abstraction volume should be researched early, corresponding measures should be brought into effect in time

① Aiming at the circumstance of eroding of retaining wall, stone must be threw to protect retaining wall, the safety of foundation of irrigation structures must be defended. The infall of pump leaks, it must be rebuilt to suit the variety of water level. Aiming at the phenomenon of crazing of dam of pump, the phenomenon must be found out, the dam of pump must be reinforced, the periodic observe is requested for insuring the safety of pump. ② For maintaining to the normal water supply of the downstream, the irrigation structures that had not abstracted water must be rebuilt or moved to set up, these measures are as follows, the size of infall should be increased, altitude of diver bottom should be debased, the irrigation structures can not used in customary place for sure, it must be moved to set up in other place. If the funds is shortage, temporary pump can construct in infall of diver.

4.4 The emerge path of abstraction water should be harnessed, ecosystem balance of the emerge path should be protected

With the decrease of abstraction water, the emerge path of abstraction water aggraded badly, its clean power descended, the water pollution turned worse, the water quality turned worse, so the emerge path of abstraction water should be harnessed to insure normal fluxion of flow. Reducing the pollution of water environment of downstream should be reduced, ecosystem balance of the emerge path should be protected.

4.5 The regulation of diver should be strengthened, the pollution of trace to the source of the emerge path should be prevented

The phenomenon of seawater trace to the source took place under the acting of tide, it is natural phenomenon. The cut degree of Beijiang River's bed was serious, the tide line moved upwards, the pollution water of the emerge path flow inversely, it brought the second pollution. Pearl Rever Delta was affected by the function of tide year by year, if it continue to extend, it will result in some problems, it includes mainly that the water of industry and agriculture is scarcity and the soil becomes salina. So the regulation of diver should be strengthened, the pollution of trace to the source of the emerge path should be prevented.

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Analysis on Water Resources and Irrigation Water of Irrigation Areas Diverting Water from Lower Yellow River

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Abstract: The Lower Yellow River irrigation areas is one of the three biggest regional irrigation areas of Yellow River Basin, belonging to irrigation – supplement zone, which has three sources of irrigation water, including the water diverted from Yellow River, the ground water and the local surface water. It is calculated that average water consumption is 14 billion m^3, among which Yellow River water is 8.84 billion m^3, ground water is 4.37 billion m^3, surface water is 0.82 billion m^3, and the respective proportion is 63%, 31%, and 6%. The total water consumption of lower Yellow River irrigation area descends gradually year by year, in which Yellow River water and surface water decrease and ground water increase slowly.

Key words: water resources, water utilization for irrigation, irrigation area of Yellow River, the Lower Yellow River

1 General introduction of the Lower Yellow River irrigation area

The Lower Yellow River irrigation areas refer to irrigation areas which diverts water from lower Yellow River between Taohuayu and estuary. Yellow River is the main irrigation water source. The irrigation areas are across through Yellow River basin, Huaihe River basin and Haihe River basin, involved cities as Jiaozuo, Xinxiang, Zhengzhou, Kaifeng, Shangqiu, Puyang, Hebi, Anyang in Henan Province, Heze, Jining, Liaocheng, Bingzhou, Dezhou, Taian, Jinan, Zibo, Dongying in Shandong Province.

At present, there are 98 irrigation areas in Henan and Shandong along the lower Yellow River. Every irrigation's area is over 667 hm^2. Therein there are 11 oversize irrigation areas whose area is more than 66.7 thousand hm^2, 26 large irrigation areas whose area is between 20.0 and 66.7 thousand hm^2 and 61 middle irrigation areas whose area is less than 20.0 thousand hm^2. Planning total ground area and plantation area is 64,076 km^2 and 3,890 thousand hm^2 respectively. The total design irrigation area is 3,580 thousand hm^2, thereinto, normal irrigation area 2,450 thousand hm^2, source – replenished irrigation area 1,130 thousand hm^2, effective irrigation area 2,580 thousand hm^2 (see Table 1).

Table 1 Basic condition of irrigation areas in Lower Yellow River

Subarea	Number of different scale of irrigation areas ($10^4 hm^2$)				Acreage (km^2)	Cropland area ($10^4 hm^2$)	Designed irrigation area ($10^4 hm^2$)			Effective irrigation area ($10^4 hm^2$)
	Oversise	Large	Middle	Total			Normal	Source – replenished	Total	
Henan	2	8	16	26	19 973	129.6	70.9	50.3	121.1	68.7
Shandong	9	18	45	72	44 103	259.5	174.3	62.5	236.8	189.3
Lower YR	11	26	61	98	64 076	389.1	245.2	112.7	357.9	258.0

1.1 Physical geography

The lower Yellow River Irrigation areas are in Huang – Huai – Hai plain which belong to warm temperate zone, semi – humid monsoon climate. Average annual precipitation is 510 ~ 790 mm. The Amount of precipitation from June to September accounts for 65% ~ 80%; rain and snow is scarce in winter; it is arid in spring. Trend of precipitation: south is more than north; it's decrease along YR gradually. Mean annual evaporation is 1,100 ~ 1,400 mm; mean temperature of air is 12.2 ~ 14.7 ℃; daylight hour are 2,200 ~ 2,750 h.

Yellow River is the biggest river crossing irrigation areas and is the main water source as well. Besides, there are many rivers that are in Huang – Huai – Hai water system crossing irrigation area, thereinto, 15 big rivers: Weihe, Tianranwengyanqu, Jindihe, Tuhaihe, Dehuixinhe, Majiahe, Zhangweixinhe in left bank; Jialuhe, Huijihe, Dongyuhe, Wanfuhe, Zhuzhaoxinhe, Liangjiyunhe, Dawenhe, Xiaoqinghe etc. in right bank.

1.2 Society economy

At present, there are $5,271 \times 10^4$ people who benefited from the Lower YR, thereinto, agricultural population accounts for 82.9%; nonagricultural population account for 17.1%. Average population density is $573/km^2$.

Lower Yellow River Irrigation areas are important yield bases of crops, cotton and oil. It plays an important role in crop, cotton, oil production in Henan and Shandong province. At present, total crop area of irrigation area is 618×10^4 hm^2, thereinto, grain crop area accounts for 72%; cotton crop area accounts for 7%; oil plants crop area account for 7%; vegetable crop area accounts for 11%; other crop area accounts for 3%. Multiple crop index is 1.75. Output of grain, cotton, oil plants are $2,312 \times 10^4$ t, 46×10^4 t, 187×10^4 t respectively in the irrigation areas.

1.3 Yellow River diversion works

At present, there are 230 diversion works on the Lower Yellow River, thereinto, 117 sluices, 110 pumping station and 3 siphons. There are 55 diversion works in Henan irrigation area, thereinto, 48 sluices, 4 pumping station and 3 siphons; There are 175 diversion works in Shandong irrigation area, thereinto, 69 sluices and 106 pumping station. Design diversion capacity of headwork is $4,047.1$ m^3/s, thereinto, $1,283.8$ m^3/s in Henan irrigation area, $2,763.3$ m^3/s in Shandong irrigation area. Total permissive fetching quantity of water is 10.1 billion m^3, thereinto, 3.05 billion m^3 in Henan, 7.06 billion m^3 in Shandong (Table 2). Otherwise, there are many water works for groundwater and surface water such as electromechanical well, dyke, sluice and irrigation and drainage pumping station etc. There are 88 plain reservoirs for impounding water from the Yellow River built in Shandong irrigation area and the total design capacity is 0.78 billion m^3.

Table 2 Statistics of YR diversion works on the Lower Yellow River

Type	Henan		Shandong		Lower YR	
	NUM	Permissive fetching quantity of water ($10^8 m^3$)	NUM	Permissive fetching quantity of water ($10^8 m^3$)	NUM	Permissive fetching quantity of water ($10^8 m^3$)
Sluice	48	29.02	69	69.44	117	98.46
Pumping station	4	1.24	106	1.14	110	2.38
Siphon	3	0.29	0	0	3	0.29
Total	55	30.55	175	70.58	230	101.13

1.4 Irrigation area

Through many years' development, three irrigated mode as gravity irrigation, lifting irrigation and supplementing irrigation are established in irrigation area on the lower YR.

According to statistics of the irrigation area, from 1991 to 2003, average annual actual irrigated area is 198×10^4 hm^2 in irrigation area on the lower YR; the biggest is 254×10^4 hm^2 in 2002; the least is 170×10^4 hm^2 in 1991. Trend of actual irrigated area is adding slowly; average annual increment rate is 3% (Fig. 1).

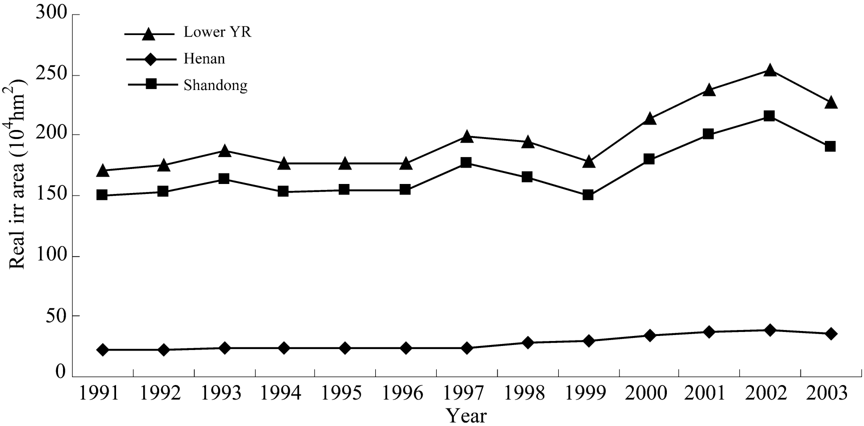

Fig. 1 Hydrograph of actual irrigated area in irrigation area of the Lower YR

Thereinto, average annual actual irrigated area is 28×10^4 hm^2 in Henan irrigation area; the biggest is 38×10^4 hm^2 in 2002; the least is 22×10^4 hm^2 in 1991. Average annual increment rate of actual irrigated area is 4%. Average annual actual irrigated area is 170×10^4 hm^2 in Shandong irrigation area; the biggest is 216×10^4 hm^2 in 2002; the least is 149×10^4 hm^2 in 1991. Average annual increment rate of real irrigated area is 3%.

2 Water resource of lower Yellow River irrigation areas

2.1 Local water resource

2.1.1 Precipitation

Precipitation is the main replenishment of local surface water and groundwater in the lower Yellow River irrigation areas. Its amount and distribution play important role in regional water inflow. According to data system of irrigation area, mean annual precipitation is 606 mm; total water resource is 38.9 billion m^3 in irrigation area through diversion from the lower YR. Different type year's annual precipitation: $P = 20\%$ is 740 mm, $P = 50\%$ is 591 mm, $P = 75\%$ is 487 mm, $P = 95\%$ is 361 mm。 Mean annual precipitation of Henan and Shandong province are 622 mm and 599 mm respectively. Precipitation in Henan is more than that in Shandong (Table 3).

Table 3 Precipitation eigenvalue of irrigation area through diversion from the lower YR

Subarea	Years mean		Different guarantee ratio of annual precipitation (mm)			
	Annual precipitation (mm)	Total annual precipitation ($10^8 m^3$)	20%	50%	75%	95%
Henan irrar	622	124.3	753	608	504	382
Shandong irrar	599	264.2	734	583	479	352
Lower irrigation area	606	388.5	740	591	487	361

From the table, precipitation decrease from southwest to northeast along the YR in the irrigation area gradually; it is more in YR south bank than that in YR north bank. Mean annual precipitation is below 600 mm in Henan and Shandong plain of north of YR and estuary that is under the Jiyang of YR; Mean annual precipitation is high in south of Henan irrigation area, east region of Henan and south Heze of Shandong; it's between 650 and 730 mm.

Average precipitation of 1991 ~ 2003 is below normals in Henan and Shandong Province. The average precipitation is 603 mm in Henan irrigation area, the biggest is 899 mm (2003), the least is 369 mm (1997). The average precipitation is 587 mm in Shandong irrigation area, the biggest is 855 mm (2003), the least is 367 mm (2002) (Fig. 2).

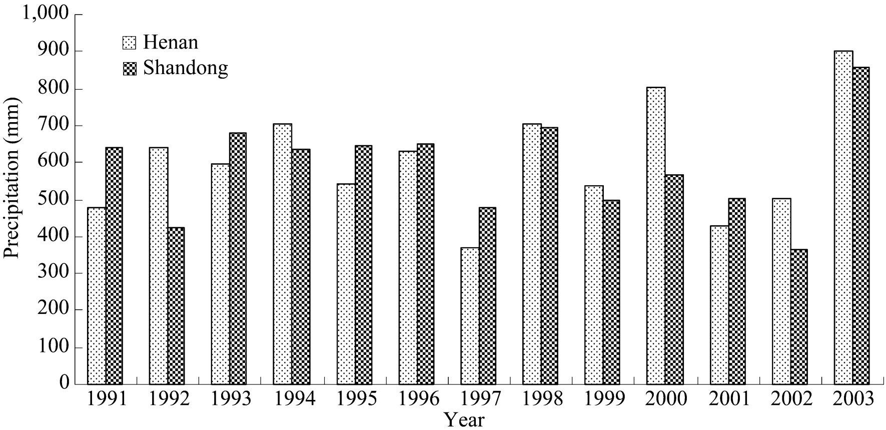

Fig. 2 Precipitation hydrograph of irrigation area of the Lower YR

Precipitation of irrigation area concentrate in flood season (Jun to Sep) mainly, occupying 70% of total; it is small in Mar. to May, occupying about 16% of total (Fig. 3).

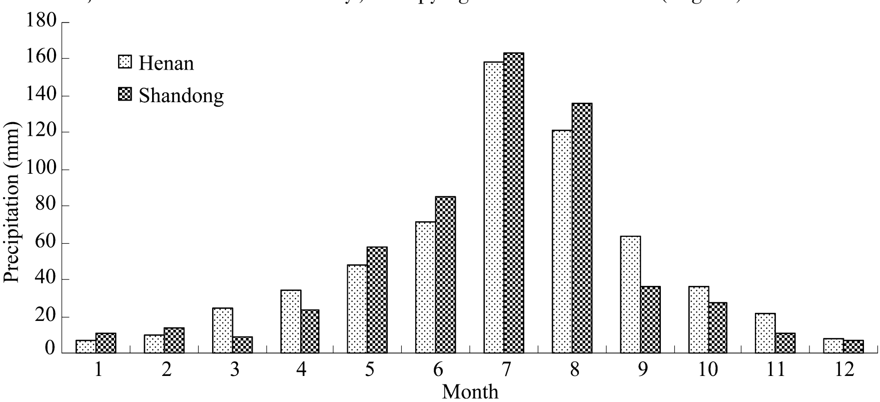

Fig. 3 Precipitation hydrograph of irrigation area of the Lower YR in a year

2.1.2 Local surface water resource

Mean average depth of runoff is parallel with precipitation in irrigation area through diversion from the YR. It decrease from southwest to northeast gradually and the difference is between 100 and 25 mm; the difference is between 40 and 80 mm in most region. In Majiahe northwest region the depth of runoff is less than 40 mm, thereinto, only 25.3 mm in Tuhaihe and Majiahe of north Henan. Depth of runoff reaches to the biggest of 159.6 mm in mountainous area of Shandong along the YR. Table 4 shows eigenvalue of runoff in irrigation area through diversion on the lower YR.

Table 4 Zoning eigenvalue of natural runoff in irrigation area through diversion from the Lower YR

Subarea	Years mean		Different guarantee ratio of annual runoff ($10^8 m^3$)			
	Depth of annual runoff (mm)	Annual runoff ($10^8 m^3$)	20%	50%	75%	95%
Henan	61.1	12.2	17.9	10.3	6.3	2.7
Shandong	61.9	27.3	42.9	19.7	9.4	6.6
Lower irrigation area	61.6	39.5	60.8	30.1	15.6	9.3

2.1.3 Groundwater resource

Irrigation area downstream of the Yellow River is mostly in the plain; the groundwater is supplied by the local precipitation infiltrate, irrigation infiltrate, surface water infiltrate, the mountain lateral infiltrates and so on, and drainaging through manual mining, unconfined water evaporation, groundwater runoff and so on. Years average amount of groundwater resource (total dissolved solid < 2 g/L) is 10.1 billion m^3 in the irrigation area. The ground water resources modulus is correspondingly 158 000 m^3/km^2. In Henan and Shandong irrigation area, years average amount of groundwater resource is 35.5×10^8 m^3 and 65.6×10^8 m^3 respectively (Table 5).

Table 5 Amount of groundwater resource of irrigation area on the Lower YR

Subarea	Ground water quantity ($10^8 m^3$)	Ground water modulus ($10^4 m^3/km^2$)
Henan	35.5	17.8
Shandong	65.6	14.9
Lower irrigation areas	101.1	15.8

According to study results on groundwater of Henan and Shandong provinces, Xinxiang and Kaifeng City that is near by the YR; the same to the area that is between Jingdihe of Puyang and YR. Groundwater resource modulus is $20 \times 10^4 \sim 25 \times 10^4$ m^3/km^2. Puyang—Qingfeng—Nanle area, north of the Puyang City, groundwater resource is deficient, groundwater resource modulus only $50 \times 10^4 \sim 10 \times 10^4$ m^3/km^2; Heze area, Shandong Province groundwater resources are rich; groundwater resource modulus is 17×10^4 m^3/km^2, north Shandong plain and estuary area about 14×10^4 m^3/km^2, the lowest of 10×10^4 m^3/km^2 in Shandong along the Yellow River mountainous area only.

2.1.4 Gross amount of water resources

Because the surface water and the ground water transform mutually, between them has the close relation, therefore the regional gross amount of water resources is equal to surface water resources amount plus groundwater resources amount minus repetitive water which is between both transforms mutually.

According to the analysis on the related results of Henan and Shandong. The irrigation area years mean surface water amount of resources is 39.5×10^8 m^3, the ground water amount of resources is 1×10^8 m^3, the repetition calculates the water volume is 17.3×10^8 m^3, the years mean water amount of resources is 123.3×10^8 m^3, its corresponding water resources modulus is 19.2×10^4 m^3/km^2. Years mean water resources total quantity of the irrigation area in Henan and Shandong is 38.9×10^8 m^3 and 84.5×10^8 m^3 respectively (Table 6).

Table 6　Gross amount of water resources of irrigation area on the Lower YR

Unit: water resource $10^8 m^3$, module $10^4 m^3/km^2$

Subarea	Surface water resources amount	Groundwater amount	Overlap water amount	Gross amount of water resources	Gross water resources modulus
Henan	12.2	35.5	8.8	38.9	19.5
Shandong	27.3	65.6	8.4	84.5	19.1
Lower irrigation areas	39.5	101.1	17.3	123.3	19.2

2.2　Runoff of the Yellow River

Yellow River is the largest across border river on the irrigation area by withdrawing water from the Yellow River downstream and the main irrigation water source. According to the analysis on data measured from the Huayuankou Hydrologic Station in 1951 ~ 2003, the Huayuankou Station years mean amount of runoff was 391×10^8 m^3. On the 20th century except the annual runoff surpasses years mean values in 1950s, 1960s and 1980s, that are lower than years mean values in 1970s and 1990s, thereinto, the value measured in 1997 has been at the least one for the record of more than 50 years, year amount of runoff is only 143×10^8 m^3, accounting for 36% of years mean amount of runoff; At the beginning of the 21st century, year amount of runoff at Huayuankou station is only 219×10^8 m^3, the amount of runoff still paced back and forth in the low position (Fig. 4).

During 1991 ~ 2003, annual runoff is 231×10^8 m^3 in the Huayuankou station, only occupying 59% of mean annual runoff, reducing 41% of runoff compared to the normal year, that date is dry season since the century 1950s to Yellow River. In 2001 ~ 2003, 21st century , the mean annual runoff only was 211×10^8 m^3, reducing 46% of mean annual runoff (Fig. 5).

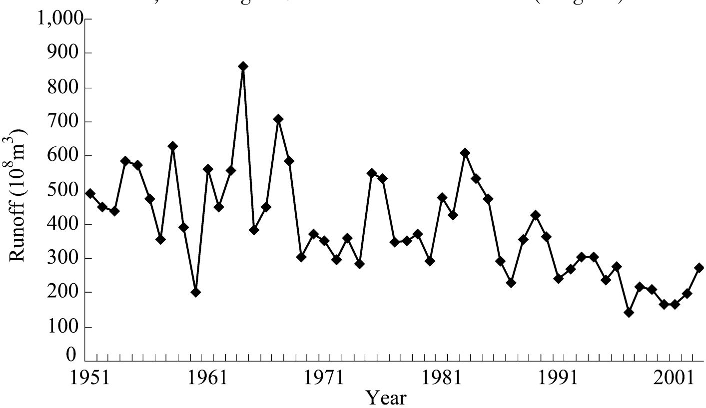

Fig. 4　Change of runoff in Huayuankou Hydrology Station

Runoff of the Yellow Rive is mainly in the flood season (July ~ October), it occupies 56% of the annual runoff, the amount of runoff in the dry season (November ~ next April) only occupies 32% of annual runoff. Affected by the climatic changing and the impounding and regulating of reservoir on main stem upstream of the Yellow River, water inflow of the Yellow River in flood season indicate obvious drop tendency. Compared with the year of 1991 ~ 2003 and 1951 ~ 2003, each month of water volume of the Yellow River was generally small, from July to November, water inflow volume only is 39% ~ 52% of the mean annual water inflow, thereinto, that in flood season (July ~ October) only 47% of the mean annual water inflow , in spring irrigation time (March ~ May) only 80%.

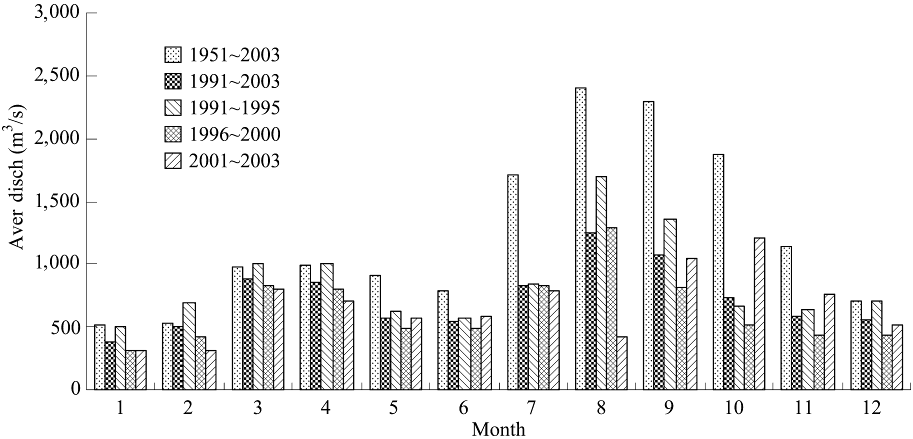

Fig. 5 Distribution of discharge in Huayuankou hydrology station

3 Status quo of Water resources development in irrigation area of the lower YR

The irrigation area of the Lower YR is developed gradually along with the new China ' s establishment. In 1952 the irrigation area named Renmin shengliqu were founded in Henan Province, which was the beginning of diverting YR water to irrigation area on a large scale. Then the irrigation area has passed through a winding development path that grow out of nothing to use YR water. From diverting and gathering greatly to stop to father. Because of "diversion" and "stop", summarizing the experiences, and analyzing the "advantages" and "shortcomings", we have adopted guidelines of "positive and prudent" for diverting YR water to use. By restoring on century 1970s, the work of diverting YR water entered the stable development stage.

In late 1990s, along with the fast development of basin economy, the requirement for Yellow River water is becoming more and more, in addition to the decreased water quantity on upstream of Yellow River, the problem of Yellow River breaking is more and more serious. In 1997, the breaking time of Yellow River downstream was as long as 226 days on Lijin cross section, breaking section reaching nearby Kaifeng of Henan Province, breaking river length reaching 704 km. It has had very tremendous influence on water use in the irrigation area of Henan and Shandong. Because of the shortage of irrigation water, it causes underproduction or planting structure adjustment. In Shandong irrigation area there are many plain reservoirs built, gathering in winter and irrigating in spring. Partial irrigation areas adopt irrigating ahead of time; In Henan and Shandong it measures come on in abundance, encouraging the irrigation area to construct mechanical well to mine ground water for irrigation to make up insufficiency of the Yellow River water. That has formed "guaranteeing the harvest by well, supplementing water source through diversion from the YR" irrigation pattern. In 2002, the actual area of irrigation area of the lower Yellow River achieve 2 540 thousand hm^2, the irrigation area water consumption achieved 1.56 billion m^3, creating a new high in the last few years.

At present, the irrigation area already formed multiplex water used pattern, the Yellow River water, the ground water, and local surface water all were used, and different areas had different water use composition.

3.1 Amount of diverting water from Yellow River

According to the statistics of amount of water diversion of sluices in the lower Yellow River , During 1970 ~ 2003, accumulative total diversion volume from the Lower Yellow River are 313.73

billion m^3, mean annual 9.23 billion m^3.

During 1991 ~ 2003, accumulative total diversion volume from the Lower Yellow River are 114.9 billion m^3, mean annual 8.84 billion m^3, in which the most water diversion volume from YR is 1.07 billion m^3 (1992), the least 5.3 billion m^3 (2003), assuming the slow drop tendency (Fig. 6). Thereinto, in the Henan irrigation area mean annual amount of water utilization is 2.02 billion m^3, accounting for 23% of total; In the Shandong irrigation area that is 6.82 billion m^3, accounting for 77%.

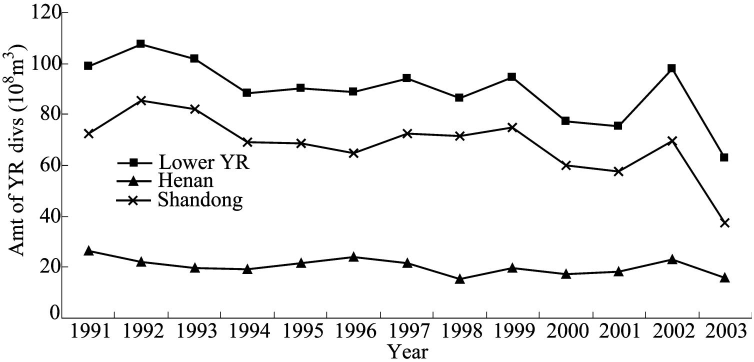

Fig. 6 Course of water diverted from the Lower YR

3.2 Amount of groundwater utilization

During 1991 ~ 2003, in the Lower YR irrigation area amount of extraction groundwater for agricultural irrigation was 4.37 billion m^3, in which the most was 5.76 billion m^3 (2002); the least was 3.64 billion m^3 (1994), assuming a slow trend of escalation (Fig. 7). Among them, in the Henan irrigation area the amount of average underground water utilization was 2.2 billion m^3; the most was 2.78 billion m^3 (2002), the least was 1.68 billion m^3 (1994). In the Shandong irrigation area the amount of average underground water utilization was 2.17 billion m^3, the most was 2.97 billion m^3 (2002), the least was 0.161 billion m^3 (1991). In the Henan and Shandong irrigation area, amounts of underground water utilization account for respectively about 1/2 of total.

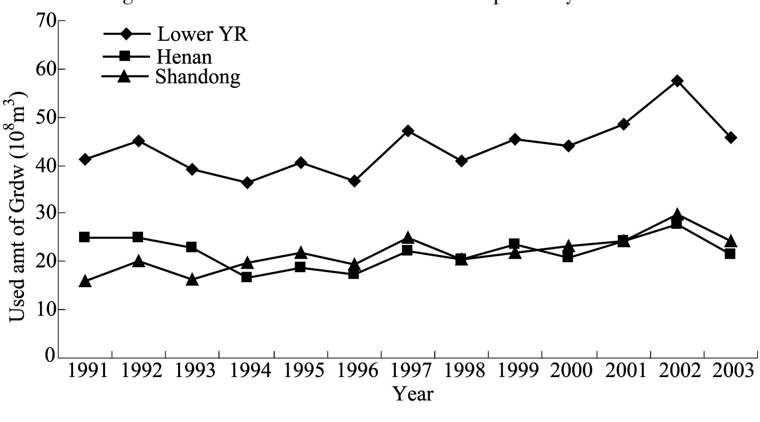

Fig. 7 Course of used groundwater in irrigation area on the Lower YR

3.3 Amount of surface water utilization

During 1991 ~ 2003, the amount of local surface water utilization for agricultural irrigation in the Lower YR irrigation area was 820 million m^3; in which the most was 1.1 billion m^3 (1992); the least was 0.54 billion m^3 (2002). Amount of local surface water utilization was in undulation and slow drop (Fig. 8). Among them, in the Henan irrigation area amount of average local surface water utilization for agricultural irrigation was 0.2 billion m^3; the most was 0.25 billion m^3 (1993); the least was 0.13 billion m^3 (2003). In the Shandong irrigation area amount of average local surface water utilization for agricultural irrigation was 0.62 billion m^3, in which the most was 0.86 billion m^3 (1998); the least was 0.35 billion m^3 (2002).

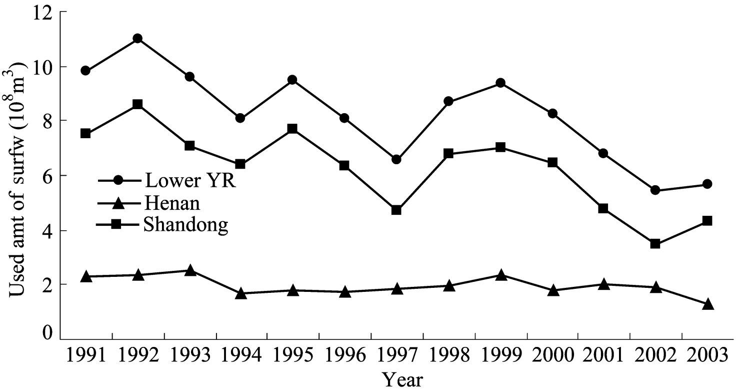

Fig. 8 Course of used surface water in irrigation area on the Lower YR

3.4 Gross amount of water utilization in the irrigation area through diversion on the Lower YR

During 1991 ~ 2003, in the lower YR irrigation area mean annual water consumption was 14 billion m^3, in which the YR water consumption was 8.84 billion m^3; the underground water conservation was 4.37 billion m^3, the local surface water conservation was 0.82 billion m^3, occupying 63%, 31%, 6% of the total water consumption separately (Fig. 9). In the Henan and Shandong irrigation area water consumptions from different water sources had large differences. In the Henan irrigation area the Yellow River water and the ground water were the primary irrigational water sources, occupying 46%, 50% of the total water consumption separately; in the Shandong irrigation area the Yellow River water was the primary irrigational water sources, occupying 71% of the total water consumption, the ground water only accounts for 23%; in the two provinces the proportion of local surface water utilization was both quite low, about 4% ~ 6%.

3.5 Analysis of gross amount of water utilization in the irrigation area on the Lower YR

If we divide the period from 1991 to 2003 into three intervals: 1991 ~ 1995, 1996 ~ 2000, 2000 ~ 2003, we can see that, the total water use in the irrigation areas of the Lower Yellow River and Henan and Shandong assumes a slow drop tendency. The water used at the three intervals were 14.7 billion m^3, 13.9 billion m^3 and 13.0 billion m^3 respectively, among which Henan's numbers respectively were 4.55 billion, 4.24 billion m^3, 4.52 billion m^3, and Shandong's numbers respectively were 10.2 billion m^3, 9.71 billion m^3, 8.52 billion m^3. The water consumption change of different water source presents a situation of "two low and one high": water diversion from

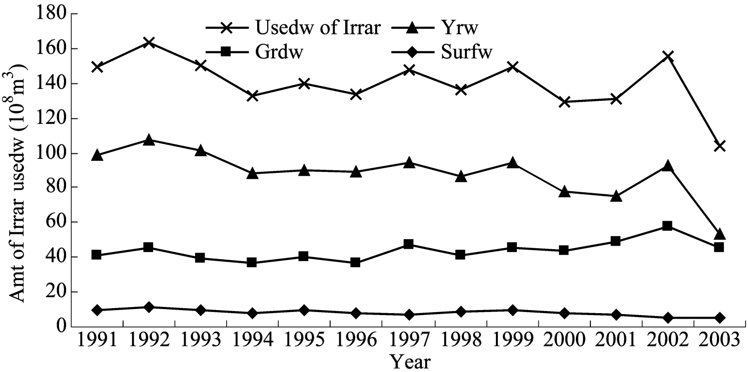

Fig. 9 Course of water use in irrigation area of the Lower YR

Yellow River and local surface water use reduce gradually and underground water use increases gradually. The proportion of the diverted water use during the three intervals in the total water use dropped to 63% and 57% from 66% and the local surface water use dropped to 6% , 5% from 7% ; On the contrary, the underground water use rised to 31% , 39% from 27%. In the Henan and Shandong irrigation area that also have the similar change tendency (Fig. 10).

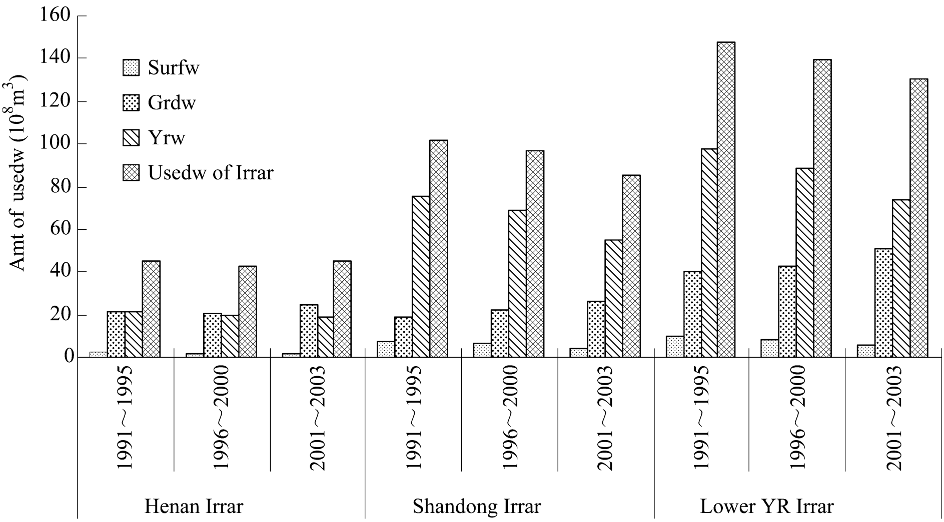

Fig. 10 Histogram of classified used water in irrigation area of the Lower YR

4 Conclusions and suggestions

(1) The mean annual precipitation in the lower Yellow River irrigation areas is between 510 ~ 790 mm, belonging to irrigation – supplement zone. Since 1990s, along with the development of society and economy in YR basin, water inflow of lower YR decreased year by year, at the same time, the lower Yellow River irrigation areas increased slowly. In order to solve water shortage of YR basin, Yellow River conservancy Commission start to attempter the water of the entire river, strengthening supervision and inspection of water utilization along YR. In Henan and Shandong province which are in the lower YR also increase the water saving construction in irrigation area, develop subsequently necessary and water saving project transformations of the irrigation area using

the national debt fund, enhance the water used efficiency, and simultaneously increase the local water resources using quantity. It has already been formed the pattern which make use of the Yellow River water, ground water, and local surface water. Therefore, although the irrigation area increased, agricultural water from the YR consumption of the irrigation area descended.

(2) The design irrigation area of the irrigation area in the lower YR is big, through these years' development, the effective irrigation area was still less than 3/4 of design irrigation area. In view of the flinty water resources situation in the Lower Yellow River, the irrigation scale wouldn't be expanded right along. We should base opon the existing scale, not increasing the irrigation water, through the water saving project technological transformations, expand the effective irrigation area.

(3) Since 1990s, the irrigation water from the Lower Yellow River has decreased gradually and the underground water for irrigation has gradually increased, that is joyful. But the irrigation area' span is big and water resources of each place has big difference, it would plan the irrigation water sources of the irrigation areas scientifically, maintaining well ecological environment of irrigation area. Such as the north of Henan and Shandong as well as the estuary, the precipitation is small, low water level or bad water quality of groundwater, that would increase diversion water from the YR, decreasing the groundwater mining quantity; Near the Yellow River, in gravity irrigation area, the water level is high, it would increase the groundwater mining quantity, decreasing water diversion.

(4) According to the differences between Henan and Shandong irrigation area in precipitation, it would appropriately adjust distributed YR water quota of the two provinces in irrigation time. Such as the Shandong irrigation area, every year in March, April and September ~ November the precipitation is small, then increasing these 5 months' YR water quota; in May ~ August the precipitation are big, then decreasing these 4 months' YR water quota.

From now on, as long as enhancing engineering construction and water use management of the irrigation area, persisting on water saving irrigation, using the local water resources reasonably, adjusting industrial structure positively, developing high quality, high production, highly effective agriculture, then irrigational benefit and agricultural output of the irrigation area will be enhanced continuously, moreover, irrigation area needn't add amount of using water; it provides strong power for benefiting local farmer, increasing agricultural output, developing the countryside, then, the irrigation area through diversion on the lower Yellow River would step onto benign development road.

Analysis of Influencing Factors of Water Consumption in Irrigation District of the Lower Yellow River

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Abstract: Sixteen mutually independent indexes were selected from 23 irrigation districts of the lower reaches of the Yellow River (IDLRYR). By principal component analysis, the paper indicated that two principal components about IDLRYR are water resource consumption situation and local social – economic condition. Meanwhile the path analysis result showed that agricultural irrigation water consumption and agricultural total output value were the main influencing factors on gross water consumption.
Key words: IDLRYR, irrigation water consumption, principal component analysis, path analysis

1 Introduction

There are many factors that affect water consumption of irrigation district. In term of 23 typical diversion irrigation districts' data in 2004 , 16 independent indexes were selected to analyze influence factors on water consumption. The indexes includes: field water utilization coefficient (C_f), channel water utilization coefficient (C_c), agricultural population(P_a), GDP of primary industry(GDP_1), GDP of secondary industry (GDP_2), GDP of tertiary industry(GDP_3),farmer's per capita net income(I_f), agricultural total output value (PV_a), domestic water consumption (W_d), industrial water consumption (W_i), agricultural irrigation water consumption (W_a), agricultural water price(P_a),local surface water irrigation area(A_s), grounder water irrigation area (A_g),Yellow River irrigation area(A_y), other water resource irrigation area(A_0). With SPSS (Hao Liren, Fan Yuan, Hao Zheou, 2002) and other software, data analysis is implemented in this paper.

2 Situation of IDLRYR

The IDLRYR Locates in semi – humid monsoon climate zone. The average annual precipitation ranges from 510 mm to 790 mm, and the main of them takes place in June to September with 65% ~80% of the whole year. There is little precipitation in winter and spring. Mean annual evaporation in IDLRYR Varies from 1,100 to 1,400 mm, and its mean temperature is about 12.2℃ to 14.7 ℃. Sunshine duration of the region is 2,200 to 2,750 hours per year. IDLRYR is a vital important base on food and cotton production in China; it plays an important part in insuring food security of Henan and Shandong Provinces after foundation of new China. Irrigation districts mainly distribute along the Yellow River in Henan and Shandong Provinces and Wen River Basin. There is about 2,147 thousand ha of available irrigation area in IDLRYR and about 1.30×10^{10} m^3 of water resource of Yellow River is used in the region. Total water consumption of agricultural irrigation in IDLRYR accounts for more than 85.0% of that of the lower reaches of the Yellow River.

3 Principal components analysis about influencing factors on irrigation water consumption

Typical irrigation districts of 23 were selected in IDLRYR, and 16 indexes as mentioned above were used to analyze with principal component analysis. In analyzing, the author eliminated missing value and calculated factor score with regression method. Table 1 is total variance explained. It can be seen in Table 1 that there are four eigenvalues higher than 1.0, and it is to say that the four principal components are significant. The cumulative contribution rate of the first and second principal components is higher than 75.0%, so the two principal components can be used to represent the whole situation of IDLRYR considering more indexes were selected.

Table 1 Total variance explained

Component	Initial Eigenvalues		
	Total	Variance(%)	Cumulative(%)
1	10.69	66.8	66.8
2	1.31	8.2	75.0
3	1.10	6.9	81.9
4	1.02	6.3	88.2
5	0.78	4.8	93.1
6	0.56	3.5	96.6
7	0.41	2.5	99.1
8	0.08	0.5	99.6
9	0.04	0.0	99.9
10	0.13	0.3	100.0
11	0.00	0.0	100.0
12	0.00	0.1	100.0
13	0.00	0.0	100.0
14	0.00	0.0	100.0
15	0.00	0.0	100.0
16	0.00	0.0	100.0

Table 2 is component matrix. The table shows that the first principal component not only includes societal and economic factors but also water using factors. The secondary principal component mainly reflects water price and farmer's net income. But this result is difficult to explain. To simplify factor's exploitation, it rotated the component matrix with varimax method (Table 3).

Table 2 Component matrix

	Component			
	1	2	3	4
GDP_2	0.972	0.103	−0.039	−0.150
V_a	0.972	0.105	−0.065	−0.142
GDP_3	0.971	0.132	−0.013	−0.153
GDP_1	0.967	0.106	−0.173	−0.104
W_a	0.936	0.080	−0.103	0.017
A_y	0.921	−0.167	0.201	0.252
A_g	0.919	−0.168	0.203	0.253
A_s	0.919	−0.174	0.199	0.248
A_0	0.919	−0.168	0.204	0.253
W_d	0.879	−0.109	−0.219	0.009

Continued to Table 2

	Component			
	1	2	3	4
P_a	0.821	−0.013	−0.413	−0.007
W_i	0.766	−0.191	0.089	0.005
C_c	0.697	0.485	0.008	−0.257
P_a	0.086	0.725	−0.282	0.314
I_f	0.224	0.392	0.745	−0.343
C_f	−0.291	0.415	0.172	0.635

Table 3 Varimax rotated component matrix

	Component			
	1	2	3	4
A_0	0.930	0.325	0.085	−0.024
A_g	0.930	0.325	0.085	−0.025
A_y	0.930	0.328	0.084	−0.024
A_s	0.929	0.327	0.080	−0.032
W_i	0.669	0.380	0.061	−0.189
W_a	0.652	0.684	0.032	0.026
W_d	0.633	0.632	−0.146	−0.109
GDP_2	0.612	0.758	0.161	−0.075
GDP_3	0.608	0.757	0.195	−0.056
V_a	0.606	0.768	0.138	−0.066
GDP_1	0.587	0.800	0.035	−0.032
P_a	0.489	0.763	−0.262	−0.030
C_c	0.240	0.652	0.377	0.151
I_f	0.105	0.089	0.927	−0.002
C_f	−0.002	−0.388	0.048	0.732
P_a	−0.117	0.338	−0.033	0.764

Therefore, the influencing factor of water consumption in IDLRYR could be divided into two parts. The first is water utilization situation as the first principal component; the second is local social and economic condition as the second principal component. And water utilization situation includes 7 indexes as following: Domestic water consumption (W_d), Industrial water consumption (W_i), Agricultural irrigation water consumption (W_a), Yellow River irrigation area (A_y), Local surface water irrigation area (A_s), Grounder water irrigation area (A_g), Other water resource irrigation area (A_0). Local societal and economic condition includes 5 indexes: Agricultural population (P_a), GDP of the primary industry (GDP_1), GDP of the secondary industry (GDP_2), GDP of the tertiary industry (GDP_3), Agricultural total output value (V_a).

4 Path analysis based on gross water consumption of IDLRYR

Take gross water consumption as dependent variable (Y), and each principal component as independent variable to implement path analysis.

4.1 Path analysis on the first principal component

The first principal component includes irrigation area and water consumption amount. Because the dependent variable is gross water consumption, the analysis for the first principal component is only to water using units. Additionally water consumption is not only about agriculture, industry and domestic but also fishery, green land and the other aspects. But there is not integrated data on each water consumption units; it only analyzes domestic water consumption (W_d), industrial water consumption (W_i) and agricultural irrigation water consumption (W_a). Limited to the length, only results is given here. The determinant coefficient $R^2 = 0.990$, and multiple correlation coefficient $R = 0.996$. And the critical value in this analysis is $R_{0.05} = 0.635$, $R_{0.01} = 0.682$. It is known that this analysis is significant different at $p < 0.01$. The result of path analysis on the first principal component to the gross water consumption can be seen in Table 4.

Table 4 Path analysis on the first principal component to the gross water consumption

Path	Direct effect b_t	Indirect effect	$b_t \times r_{kt}$	Total effect r_{ky}
W_a to Y	0.727*	W_d W_i	0.140 0.109	0.976**
W_i to Y	0.160	W_d W_a	0.122 0.494	0.776*
W_d to Y	0.188	W_i W_a	0.103 0.542	0.833**

Table 4 indicates that the direct effect of W_a on Y is significant different at $p < 0.05$, and the total effect of W_a to Y is significant at $p < 0.01$.

There are no significant different for the direct effects of W_i to Y and W_d to Y, but the indirect effects which they play to Y is high, so the total effects of W_i to Y and W_d to Y are significant at $p < 0.05$. It can be seen from Table 4 that agricultural irrigation water consumption is the most important factor to the gross water consumption and the indirect effect which played by W_a is the highest in the three. IDLRYR should explore water saving potential and optimize water distribution in different water using units from the results analyzed above.

4.2 Path analysis on the second principal component

The second principal component includes social and economic factors. In this paper, the economic factors are set into path analysis considering the dependent variable is the gross water consumption. It can be seen from Table 5 that the direct effect on GDP_1 GDP_2 and GDP_3 are not significant different to Y but agricultural total output value (V_a). And GDP_3 plays a negative effect on the gross water consumption (Y). But indirect effect of GDP_3 though the other factors are positive, and its total effect is significant different at $p < 0.01$. In other words, the indirect effect of GDP_3 through the other economic factors counteracts the direct effect that it does to Y. It can also be seen from Table 5 that effects of V_a play a significant role in gross water consumption of IDLRYR. So V_a is the most important factor in the economic component and should be taken into account in irrigation districts valuation.

Table 5 Path analysis on the second principal component to gross water consumption

Path	Direct effect b	Indirect effect	$b_t \times r_{kt}$	Total effect r_{ky}
GDP_1 to Y	0.465	GDP_2	0.050	0.925**
		GDP_3	-0.601	
		PV_a	1.011	
GDP_2 to Y	0.051	GDP_1	0.450	0.908**
		GDP_3	-0.615	
		PV_a	1.022	
GDP_3 to Y	-0.618	GDP_1	0.453	0.912**
		GDP_2	0.051	
		PV_a	1.026	
V_a to Y	1.057*	GDP_1	0.445	0.952**
		GDP_2	0.050	
		GDP_3	-0.600	

5 Discussions

In this paper, principal component analysis was used to analyze the influencing factors on water consumption of IDLRYR. In order to simplify the results, varimax orthogonal rotation method was used. Because varimax orthogonal rotation is a method without changing original variance decomposition (Yuan Zhifa, Meng Deshun, 1992), the rotated matrix reserves the original information of situation that collected from IDLRYR. However there are short of the other information such as ecosystem water consumption. So it is necessary to analyze the situation with integrated information of IDLRYR.

It is indicated that effect of agricultural irrigation water consumption and agricultural total output value are significant to the gross water consumption through path analysis. That is to say the main water consumption concentrates on agricultural development. And GDP_3 plays a negative role in gross water consumption although this effect is not a significant one. Basing on the water saving, it recommends that the tertiary industry be speeded up under the premise of not enlarging irrigation water consumption of IDLRYR.

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Primary Research on Ecological Water Demand in Source Rivers for the First Phase West Line South – to – North Water Diversion Project

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Abstract: The field of ecological water demand has been one of the research foci of geographical sciences in the world. The calculation of ecological water demand in source rivers of the first phase western line south – to – north water diversion project is the base of water transfer scale argumentation. Based on the theory research, we considered the need of keeping river system health and protecting the plants of side banks and the living things in river reaches according to the unique eco – environment of western route in source region and the goal of environment protection. Then we selected many methods to calculate the ecological water demand in river reaches. The results stated that the ecological water demand range of various dam is Reba (27.06 ~ 40.68 m^3/s), A'an (3.8 ~ 7.41 m^3/s), Renda (2.87 ~ 6.11 m^3/s), Zhuanda (4.53 ~ 7.94 m^3/s), Huona (4.25 ~ 6.73 m^3/s), Keke (1.75 ~ 2.90 m^3/s). The ecological water demand of vegetation out of river reaches is satisfied by precipitation.

Key words: the first phase west line of south – to – north water diversion project, source river, ecological water demand

The Western Line South – to – North Water Diversion Project (the Project) is a large – scale trans – basin scheme diverting water from the upper reaches of the Yangtze River to the upper reaches of the Yellow River, being a significant strategic measure for supplementing water to the Yellow River, the arid northwest China and safeguarding the water source for management and development of the Yellow River. As planned, the Project will be implemented in three stages, respectively diverting water from the upper reaches of Yalongjiang, Dadu river and Jinshajiang at EL. about 3,500 m to the Yellow River, and the total water diversion is 17 billion m^3. At present, the proposal for the first phase Project is being undertaken, and water volume of 7.5 billion m^3 to 9 billion m^3 is to be diverted from the stem Yalongjiang and tributaries of Daqu and Niqu, and from tributaries to Dadu river, including Sequ, Duke river, Make river and Ake river.

The first phase Project is located at the transition from Sichuan Basin to Qinghai – Tibet Plateau with complicated land features, various climatic types, abundant ecological resources and unique eco – environment features. With full consideration of maintaining sustainable social and economic development and benign eco – environment in the source area, and in the evaluation of transferable water volume, the first priority is to satisfy water demand for all sectors and ecological use below the diversion dams. Ecological water demand is therefore an important basis for evaluating of transferable water volume, and it is a must to make an overall, objective, scientific and reasonable analysis for water demand by eco – environment of the source rivers to provide reliable and scientific reference for determining transferable volume of the first phase Project.

1 Eco – environment features of first phase project area

The Project area is located at southeast edge of Qinghai – Tibet Plateau, with north subtropical, warm temperate and temperate zones, and in addition, large variation in altitudes (1,600 ~ 5,000 m) leads to complicated topographies, various land features and climatic environments, and development of frozen soils and unique habitats, forming abundant and particular types of landscapes. They mainly include mountain forests, mountain thickets, arid valley scrubs, cold meadows, and swamp wetlands at high altitudes. Natural landscape presents vertical variation from valley subtropical zones to alpine permanent ice and snow belts, significant variation between zones and complex natural mountain conditions, diversity of vegetation and climate types, creating diversity of habitats. Because of insignificant influence of human activities, eco – environment basically maintains at primary natural situation and biologic diversity nearly keeps in integrity.

There are multiple types of vegetation, abundant species of plants, and composition of flora is complex, being one of the areas with abundant flora in China, and there is rich variety of plant resources. Main vegetation types include forests, mountain thickets, arid valley thickets, alpine meadows, sub – alpine meadows, swamp wetlands, alpine cushion – like vegetation and alpine flow rocks and sparse vegetation. At present, there are higher plants of 102 families, 259 genera and 680 species.

The rivers in the area are in deep valleys with steep slopes, turbulent currents and a large volume of flows and an average river width of 50m. Field investigations found 39 genera of phytoplankton, 15 species of animal plankton, 13 species of demersal animals, and 10 species of aquatic insects. Aquatic plants and invertebrates are relatively sparse. As recorded in literature, there are fishes of 3 orders, 4 families and 33 species, including 15 species of fish of Cyprinidae Schizothoracinae , being 45. 5% of the total number of natural fishes; 14 species of fish of Cobitidae Noemacheilinae, being 42% of the total; in addition, there are also 4 species of fish: Hucho Bleekeri Kimura of Salmonidae, and E. davidi, E. kishinouyei and Glyptothorax japonicus of Sisoridae. Rare species are Schizothoracinae and Hucho Bleekeri Kimura, and the special fish is Daduhe Schizopygopsis Malacanthus.

2 Ecological protection target

The ecological protection function mainly refers to maintaining aesthetic value and landscape value, protection of aquatic biologic species, transport of nutrients, flattening of flood waves and accepting discharge of groundwater. The rivers therefore need adequate flows to maintain these functions. At present, the study or the calculation of ecological water demand has made certain progress, providing basic reference for reasonable utilization of water resources. But none of the available calculation methods is commonly used for estimating ecological water demand by quantifying all parameters and reflecting influences among them. It is therefore significant to combine the multiple methods and determine ecological water demand in the river channels associated with the first phase Project in accordance with specific ecological protection targets, to fully consider water demand by eco – environment in the source area and minimize the impact of water diversion.

Different major targets of ecological protection are considered for different projects with different ecological water demands, and the targets of different priorities are formulated. For the source rivers of the first phase Project, two major targets are set up.

The first is to protect aquatic creature in the river, mainly the special fishes (e. g. Dadu river Schizopygopsis Malacanthus), and rare and endangered fishes (e. g. Hucho Bleekeri Kimura).

The second is to protect vegetation growing by waters. Primary vegetation is well protected in the area with high biologic diversity. With special topography and climatic conditions, vegetation growing far away from rivers generally receives rain water necessary for growing. And vegetation growing by waters is the key item of protection.

With satisfaction of flow demand in river channels by the two major targets, other ecological protection functions, such as aesthetic and landscape values, maintaining transport of nutrients, peak flood reduction and receiving discharge of groundwater will accordingly be realized.

3 Calculation method of ecological water demand for the project

There have been no recognized calculation methods and principles for calculating of ecological flow in channel, and different methods are used for different requirements and protection targets for the rivers in different countries and regions. With the special characteristics of the ecological system of the rivers in the Project area and ecological protection targets considered, the following principles are followed for selecting of calculation methods.

(1) Using calculation methods as much as possible

Different methods emphasize with particular aspects, and with different advantages and disadvantages. By using multiple methods, overall factors are considered for ecological water demand, and they compensate between themselves. For example, Montana method takes the predetermined annual average flow percentage as the recommended base flow of the river. This is usually used for the recommended river flow in the river reaches of lower priority, or for checking other methods. Generally 10% of mean annual flow is taken as minimum ecological water demand for the river. The method has an obvious disadvantage, that is, the important flow extremum and temporal variation of flows are excluded. And mean annual flow percentage shall also adjust to the local situation. As seasonal variation is excluded in Montana method, Texas method is used to compensate to some extent. In addition, the rate of monthly (annual) guarantee method has basically the same consideration as the Chinese 7Q10 method, which takes the lowest monthly flow with the rate of guarantee of 90% as the minimum design flow. The latter two methods are especially suitable for calculating of the basic water demand for environment in the river by dealing with the most prominent problem of pollution as the constraint, obtaining discharge of pollutants and wastewater with different targets of water quality to satisfy the dilution and self – cleaning function of the river. Multiple methods are therefore adopted on the basis of water equilibrium, and the relationship of water and salt, water and sediment.

(2) Requirement for protection of aquatic creature

In accordance with the unique eco – environment and protection objectives in the source area of the Project, for maintaining the habitat of aquatic creature, the target is to protect the precious aquatic creature in the river, particularly some special fishes like Schizothorax and Hucho Bleekeri Kimura. The methods including hydrology and biology are selected for protecting the habitat of aquatic creature to maintain sound ecological function of the source rivers.

(3) The methods unsuitable for actual situations are not adopted.

For example, sediment – flow method and sea inflow method, etc.

(4) New methods are established with the actual situations for deriving water demand for eco – environment.

The hydraulic radius method is an example.

4 Results and analysis of ecological water demand

4.1 Results of ecological flow in river channel

Annual total ecological flow in river channel is calculated by using Tennant method, minimum monthly flow method, 7Q10 method, wetted perimeter method and hydraulic radius method. These methods have results in big differences, and generally, nearly the same ecological flow is obtained by using Tennant method with 10% flow percentage and using lowest monthly flow with 90% rate of guarantee, and again the same is derived by using Tennant method with 20% flow percentage and using lowest monthly flow with 50% rate of guarantee (on an average). The value obtained by Tennant method with 30% flow percentage is bigger than that by other hydrologic methods.

Ecological flow is calculated by using hydraulic method and hydrologic method, and the value is bigger using the latter compared to the former. With all factors considered, Tennant method with 10% and 20% flow percentages and lowest monthly flow with 90% and 50% (on an average) rates of guarantee are adopted in calculation to establish the range of ecological water demand.

The comparison shows the result obtained by hydraulic method is smaller than the lower limit of ecological flow. and by satisfying only the lower limit of the above water demand, the lowest level of habitat required by aquatic creature (fish) derived by wetted perimeter and hydraulic radius methods can be maintained. Although the result of hydraulic radius method for quite a few of dam sites exceeds the upper limit, the upper limit of ecological flow determined by hydrologic method is taken as the standard.

The analysis of runoff K – M trend in the area shows obvious fall and rise of runoff at Ganzi and

Daqu, and no obvious variation of runoff trend at other dam sites. For the two locations, the recent 10 - year data are used as samples.

Table 1 Annual total ecological water demand in river channel Unit: m^3/s

Calculation method	River	Yalongjiang	Daqu	Niqu	Duke	Make	Ake
	Dam site	Reba	A'an	Renda	Zhuanda	Huona	Keke
	Mean annual flow (1960 ~ 2002) (m^3/s)	192.6	33.5	36	45.6	35.8	18.1
Hydrologic method	MEIFR_tennant_10% (m^3/s)	19.26	3.35	3.6	4.56	3.58	1.81
	MEIFR_tennant_20% (m^3/s)	38.52	6.7	7.2	9.12	7.16	3.62
Recommended result	MEIFR_tennant_30% (m^3/s)	57.78	10.05	10.8	13.68	10.74	5.43
	Minimum monthly flow (m^3/s)	44.52	6.46	5.03	6.77	6.30	2.18
	7Q10 (m^3/s)	42.83	8.13	6.88	6.71	5.93	2.09
	7Q10 (90%) (m^3/s)	34.86	4.24	2.14	4.50	4.93	1.70
	Lower limit of recommended ecological water demand	27.06	3.80	2.87	4.53	4.25	1.75
	Upper limit of recommended ecological water demand	40.68	7.41	6.11	7.94	6.73	2.90
Hydraulic method	Traditional wetted perimeter	5.70	1.70	3.40		5.50	2.00
	Hydraulic radius method	49.8	5.00	8.30		9.90	3.7

The runoff mainly maintains ecological flow in the reach downstream of the diversion dam site, and with contribution of downstream tributaries, the flow in the channel increases, and the ecological flow will rapidly rise. Meanwhile, with operation of the diversion reservoir, in many months, particularly in flood season, discharging flow from the reservoir is much greater than the required lowest ecological flow. In the 45 years runoff series, nearly 10 years have an increased minimum discharging flow in dry months compared to the level before diversion.

4.2 Analysis of ecological water demand out of channel

In simulation of monthly flows of 1956 to 1999, precipitation is always greater than actual evaporation in the river basin, indicating precipitation can satisfy the growth of vegetation, and ecological water demand out of channel (as simplified, the study object is vegetation) refers to evaporation and transpiration of vegetation, and the preliminary result shows water diversion will not affect ecological water demand out of channel.

In addition, for the study of ecological water use on river banks, the isotope analysis is carried out, finding out the relationship among channel - groundwater - vegetation. The basic result is that vegetation in channel and on banks lives on precipitation, and the channel flow depends on precipitation in flood season, and on groundwater at both banks in non - flood season; reduction of channel flows will not affect the growth of vegetation on banks, and ecological water use out of channel will not change the volume of water diversion and the rule of operation.

5 Conclusions

The present results show the source for recharging groundwater is mainly atmospheric precipitation, and with the distributed ecological hydrologic model and by field investigation, normal growth of natural vegetation associated with the first phase Project directly depends on precipitation and not any of runoff (especially channel runoff) water resources. It is therefore concluded that the source rivers of the first phase Project will be able to meet the water demand for mainly ecological purpose in channel besides production and living out of channel. In the future, such studies shall be further undertaken: requirement of habitat by aquatic creature; calculation methods suitable for ecological water demand by the Project; influence of bank vegetation by water diversion in wide and shallow river reaches.

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Research on Compensation Measures for the Impact of Western Line Works of South – to – North Water Transfer Project on Hydropower within Water Transfer Region

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Abstract: This paper definitely defines the compensation bound for impact of water transfer on hydropower, of which compensation schemes have been put forward from two aspects of economy and function, while each of which has carried through the comparison and analysis, and which has been finally recommended as the appropriate for Western Line Works of South – to – north Water Transfer Project, providing the scientific reference for engineering decision – making.

Key words: Western Line Works of South – to – north Water Transfer Project, hydropower, disadvantageous influence, compensation measure

After carrying through the Western Line Works of South – to – north Water Transfer Project, there have been disadvantageous influences of different levels affecting several aspects as environment, agricultural and industrial water – use, driftwood, shipping, and hydropower of water transfer region, while there also have been enormous benefits gained by intake area. It is an important comprising part for the Western Line Works of South – to – north Water Transfer Project Planning to analyze and study the disadvantageous influence and its compensation measures. As the much more enormous disadvantageous influence induced by the Western Line Works of South – to – north Water Transfer Project on hydropower of water transfer region, it is necessary to wholly study the compensation measure scheme for compensating the loss of hydropower induced by water transfer.

1 Compensation bound

Based on considerations on two aspects of macro – economical analysis and compensation measure research, and according to relevant laws and statutes of State, the step hydroelectric station influenced by water transfer region shall be divided into two kinds of circumstances: one is the stations constructed and under construction before the interbasinal water – transfer planning has been ratified by State Water Administrative Chief Department, the other is the stations being planed and programmed after the interbasinal water – transfer planning has been ratified by State Water Administrative Chief Department.

The influence of water transfer on the second kind of step hydroelectric station is potential and possible to happen. On Dec. 2002, State Council made an official and written reply for "The General Planning of Western Line Works of South – to – north Water Transfer Project", certificating that a certain quantity of water resources of Yangtse River shall be used for interbasinal water resources allocation, which fundamentally makes the function of this portion of water resources divert from several aspects, e. g., power production, etc. into water supply. Therefore, it shall consider the Western Line Water Transfer Project Planning in "The General Planning of Western Line Works of South – to – north Water Transfer Project", ratified and agreed by State Council, on making the planning, design and construction of long – range level year planning step for the mainstream and several distributaries as Jinsha River, Yalong River and Dadu River, to properly adjust its engineering layout, scale and relevant planning targets and to put forward the appropriate scheme for developing and utilizing, in order to adapt the runoff variation after completing water transfer and to avoid losses.

The influence of water transfer on the first kind of step hydroelectric station is practicable and concrete. After completing water transfer, the firm capacity and annual generated energy of these stations will decrease, and the benefit will lose as well. The influenced benefit of hydraulic power station is evaluated by the benefit – violated degree of these stations acquiring draft permission and water resources access through calculation, and this evaluation is the reference for analyzing the profit and loss of lawful water users, while a certain degree of afforded compensation through consideration during the item prophase performance. Under the circs of pursuing "The General Planning of Western Line Works of South – to – north Water Transfer Project" ratified and agreed by State Council including the Western Line Water Transfer Planning, it's only appropriate to consider the step hydroelectric station constructed and under construction before 2003 for the compensation of Western Line Water Transfer for disadvantageous influences of its lower step hydroelectric stations.

2 The Electric quantity loss of influenced power station

The step hydroelectric stations situated along the mainstream and tributaries of Yangtse River influenced by the Western Line Works of South – to – north Water Transfer Project and being constructed and under construction before 2003 include Gongzui and Tongjiezi of Dadu River, Ertan of Yalong River, and Three Gorges and Gezhou Dam of the Yangtse mainstream. This research performance stays in the project proposal phase of Phase I Works of Western Line of South to north Water Transfer Project, whose water transfer quantity is the annual water transfer quantity of 8 billion m^3 of the level year, 2030. In allusion to this water transfer quantity, the firm output of loss for step hydroelectric stations being constructed and under construction before 2003 within water transfer region is 130.4 thousand kW and its annual generated energy is 3.457 billion kW · h, which have respectively occupied 1.4% and 2.7% of the corresponding target of non – water – transfer phase. Detail calculation results have been listed in Table 1.

Table 1 The loss of step hydroelectric stations being constructed and under construction before 2003 induced by phase I works of western line water transfer project

Hydroelectric Station	Installed Capacity (Ten Thousand kW)	Before Water Transfer		After Water Transfer		Before – After Water Transfer	
		Firm Output (Ten Thousand kW)	Annual Average Generated Energy (Hundred Million kW · h)	Firm Output (10^4 kW) (Ten Thousand kW)	Annual Average Generated Energy (Hundred Million kW · h)	Firm Output (Ten Thousand kW)	Annual Average Generated Energy (Hundred Million kW · h)
Gongzui	70	32.75	43.95	31.26	43.24	1.49	0.71
Tongjiezi	60	26.51	37.16	26.06	36.48	0.45	0.68
Ertan	330	133.46	178.13	127.22	161.46	6.24	16.67
Three Gorges	2,240	624.64	877.45	620.51	862.68	4.13	14.77
Gezhou Dam	271.5	111.07	156.54	110.34	154.8	0.73	1.74
Total	2,551.5	928.43	1,293.23	915.39	1,258.66	13.04	34.57

3 Possible compensation measures

Considering from actual study results, compensation measures can be divided into three kinds of scheme: Economic compensation, Functional compensation and Flexible compensation. These compensation schemes and flexible measures have their own advantages and disadvantages, which respectively adapt to different circs.

3.1 Economic compensation

As for the power station management unit, to decrease the generated energy means to lower the income, and the loss is at the economic aspect, towards which the compensation carrying through just equals to the recovery of financial loss induced by water transfer. The economic compensation is of the compensation expense equaling to the calculated financial loss according to the power sale quantity lost by power station and corresponding price after deducting the reduced cost expenditure induced by decreased generated energy. The corresponding price ought to be the price of power station cost plus with rational returns.

(1) The Nonrecurring economic compensation. It's to bring the compensation net transfer of constructed works into the engineering estimate and to make the nonrecurring payment before constructing water transfer projects. For the Western Line Works of South – to – north Water Transfer Project, it can adopt the means of nonrecurring economic compensation to calculate the annual compensation expense based on annual actual loss during the performance period of water transfer project before considering the conversion from expense to current value on adequate discount rate for carrying through the nonrecurring compensation, which shall be listed into the investment of water transfer project.

(2) The economic compensation by stages and batches. It's to make the payment by stages and batches of engineering compensation fund apportioned by year from the initial operation of water transfer project on considering several factors as the useful life of constructed project, etc.. Though there has been an enormous investment for the Western Line Works of South – to – north Water Transfer Project with a strong commonweal impetus, there has been a quite smaller financial return during the engineering operation period yet with a difficult source for operation cost, while it still cannot appropriate the financing to undertake the economic compensation. Therefore, this scheme isn't applicable to the Western Line Works of South – to – north Water Transfer Project.

3.2 Functional compensation

As to the network, capacity loss (especially the peak capacity loss) and generated energy loss influence the function of network. Therefore, it shall also consider compensation measures to power station from the aspect of function. The functional compensation is to recover the capacity and generated energy losses induced by water transfer through the construction of various kinds of power station projects, while to pay relevant departments the compensation fund, namely, the expense for constructing power station projects, and then have them to take charge of the engineering construction, which can recover the functional loss of power system induced by water transfer project, and whose benefits can recover the financial loss of influenced power stations. Main compensation means include conventional hydropower station compensation, pumped storage power station plus with thermal power station compensation, and single thermal power station compensation, etc.. It can adopt corresponding compensation measures according to the circs of power station influenced by water transfer.

As for the Western Line Works of South – to – north Water Transfer Project, it cannot make much more influences on the power quantity of electricity of actually constructed power stations, and as the general tendency of state load flow is the west – to – east electricity transmitting, it's nor suitable to transmit the northerly electricity to areas of Yangtse River Upper Reach, neither suitable to have this electricity of smaller scale generated within the east China area. Up to 2030 and the large – range level, analyzing from the research and relevant materials of Yangtse River Conservancy Commission, the quantity of electricity within Southwest area will have a margin, of which the margin portion has been transmitted to areas of middle China and east China after the primary consideration. Hereby, it can be thought that as to the quantity of electricity lost by water transfer belonging to that transmitting to areas of middle China and east China, it can consider to recover the lost quantity of electricity directly to areas of middle China and east China.

3.3 Flexible compensation

(1) Assets restructuring or purchase. It's the water transfer project or some investor of this project that purchases the constructed works, which is one kind of flexible measure to bring this works into the water transfer project Due to the matters relating with assets restructuring or purchase are quite complex, this measure shall be temporarily hardly considered to be adopted during the

Western Line Works of South – to – north Water Transfer Project at present.

(2) Flexible measures as deduction or exemption for water resources occupancy expenses of constructed works or tax break, etc.. It's the water transfer project and its investors that hardly need to actually pay the fund. Therefore, its advantage is hardly to increase the fund burden of water transfer project and its investors. This kind of flexible measure is applicable to the Western Line Works of South – to – north Water Transfer Project, which can counteract a certain part of recovery cost to lighten the investment pressure of State.

4 The drafting of compensation scheme and calculation for sum of indemnity

As to previously determined compensation bound, it respectively adopts the nonrecurring economic compensation scheme and engineering compensation scheme to calculate the compensation expense for hydropower from Western Line Works of South – to – north Water Transfer Project.

4.1 Sum of indemnity for economic compensation scheme

The annual financial loss of power production co. is calculated by employing the return of unit generated energy multiplying with annually lost generated energy. The total compensation expense is calculated on considering the rational economic compensation years. The calculation formula is as follows:

$$B = \sum_{i=1}^{n} \sum_{j=1}^{m-k(i)} W_{ij} D_{ij}$$

In which: B is the total compensation expense, i is the serial number of hydropower station influenced by water transfer, n is the amount of hydropower stations influenced by water transfer, j is the compensation sequence of year, m is the economic compensation years, $k(i)$ is the operating years of hydropower station influenced by water transfer, i, before the water transfer project becomes effect, W_{ij} is the return of unit generated energy of hydropower station influenced by water transfer, i, in year j after actualizing the water transfer, and D_{ij} is the lost generated energy of hydropower station influenced by water transfer, i, in year j after actualizing the water transfer. The return of annual unit generated energy of each hydroelectric station influenced by water transfer is generally calculated by 0.04 Yuan (RMB) /(kW · h). The economic compensation years are calculated by 50 years.

As to the financial loss of step power stations constructed and under construction before 2003 induced by water transfer of Phase I Works of Western Line, if it adopts the year – after – year compensation scheme, the total sum of indemnity is 3.141 billion Yuan, while if it adopts the nonrecurring compensation scheme, the total sum of indemnity is 1.58 billion Yuan after considering the discount (the discount rate is 6.39%). Detailed calculation results have been listed in Table 2.

Table 2 The Financial loss of step hydroelectric stations being constructed and under construction before 2003 induced by phase I works of western line water transfer project

Serial Number	Power Station Name	Influenced Generated Energy (kW · h)	Buildingup Year	Required Compensation Years	Financial Loss (Hundred Million Yuan)	
					Initial Value	Net Present Value
1	Gongzui	0.71	1978	0	0	0
2	Tongjiezi	0.68	1994	14	0.38	0.25
3	Ertan	16.67	2000	20	13.34	7.41
4	Three Gorges	14.77	2009	29	17.13	7.71
5	Gezhou Dam	1.74	1988	8	0.56	0.43
6	Total	34.57			31.41	15.80

4.2 Sum of indemnity for engineering compensation scheme

It shall employ the scheme of transmitting electricity to middle China and east China by means of thermal power as the equivalent substituting engineering one, namely, first to construct the pithead coalfired thermal power station in Taiyuan City, Shanxi Province, and then to transmit long – distance electricity to areas of middle China and east China.

4.2.1 To draft the compensation scheme

There are two schemes of economic compensation for newly constructed thermal power stations towards loss – suffering hydropower stations: one is the incomplete compensation, namely, is to make economic compensations by employing the annual after – tax profit of newly constructed thermal power station with an uncertain compensation ratio; the other is the complete compensation, namely, is first to calculate the year – after – year economic loss of loss – suffering hydropower stations, which shall be then brought into the burning cost of newly constructed thermal power station with year – after – year sufficient compensations. As to these two schemes of economic compensation for newly constructed thermal power stations towards loss – suffering hydropower stations, their primary financial analysis have been respectively conducted as follow.

4.2.2 The primary financial analysis for incomplete compensation scheme

It can consider 6,000 hours as the yearly operating hour of newly constructed thermal power station, and 3.457 billion kW · h as its yearly generated energy, while it requires 605 thousand kW as the thermal power installation capacity. Calculated on 4,500 yuan/kW as the investment amount and 4 years as the investment service life, the investment ratio for each of these four years is respectively as 15%、25%、35% and 25%. The construction period is 4 years and the production operations period is 40 years. The yearly interest rate for money at long is 6.39%, and that for interim loan is 5.85%. The composition depreciation ratio is 4.75%. The coal price is calculated at 350 yuan/t, and the standard coal consumption is calculated at 320 g/(kW · h). The water consumption is 2,640 t/h, and the water fee is 1.5 yuan/t. The repair cost ratio is 2.5%, the material cost ratio is 10 yuan/(MW · h), other premium rate is 5 yuan/(MW · h), and the service power ratio is 6.26%. The fixed number of persons is counted as 182, the per capita annual salary is counted as 20,000 yuan, and the welfarism, overall labor insurance and housing fund respectively occupies 14%、17% and 10% of the sum of salary. The capital proportion is 25%, and the power grade price is 0.275,4 yuan/(kW · h).

According to above – mentioned parameter calculations, the total investment for newly constructed thermal power station is 3,015,410 thousand Yuan, among which the capital is 756,540 thousand yuan, the yearly total burning cost is 736,310 thousand yuan, and the yearly average generated energy return is 125,980 thousand Yuan. The investment recovery period is 12.59 year, the highest asset – liability ratio is 75%, the capable compensation for influenced hydropower station by utilizing the allocable return compensation is 0.034,7 yuan/(kW · h), and the financial internal income ratio of whole investment is 8.48%, while that for capital is 11.13%. The detailed indexes have been listed in Table 3.

4.2.3 The primary financial analysis for complete compensation scheme

The complete compensation scheme first requires to calculate the actually financial loss influenced by hydropower station, and then to bring this compensation expense into the total bursting cost of generated energy to conduct the financial evaluation, during which the year – by – year financial loss of hydropower calculated in Section 4.1 can be considered as the compensation expense. The capital ratio is taken as 40%, and the value assignment for other parameters is the same with that of incomplete compensation scheme. Through analyzing, the total investment of newly constructed thermal power station is 2,964,260 thousand Yuan, among which the capital is 817,680 thousand Yuan, the yearly total burning cost is 799,280 thousand Yuan, and the yearly average generated energy return is 83,200 thousand yuan. The investment recovery period is 11.76 year, the highest asset – liability ratio is 60%, the compensation return for influenced hydropower station is 0.04 yuan/(kW · h), and the financial internal income ratio of whole investment is

9.61%, while that for capital is 12.18%. The detailed indexes have been listed in Table 3.

Table 3 The item financial evaluation index sheet of newly constructed thermal power station

Serial Number	Items	Unit	Compensation Scheme	
			Incomplete	Complete
1	Total Investment	Ten Thousand yuan	301,541	296,426
1.1	Fixed Assets Formation	Ten Thousand yuan	272,250	272,250
1.2	Interest of Construction Period	Ten Thousand yuan	23,917	18,803
1.3	Liquid Funds	Ten Thousand yuan	5,374	5,373
1.4	Capital Ratio		25%	40%
1.5	Capital	Ten Thousand yuan	75,654	81,768
1.6	Bank Loan	Ten Thousand yuan	225,887	214,658
2	Power Grade Price of Operation Period	yuan/kW·h	0.275,4	0.275,4
3	Generated Energy Income	Ten Thousand yuan	93,708	93,708
4	Sales Tax and Surcharge	Ten Thousand yuan	1,274	1,274
5	Total Bursting Cost	Ten Thousand yuan	73,631	79,928
6	Generated Energy Return (After Income Tax)	Ten Thousand yuan	12,598	8,320
7	Earning Capacity Index			
7.1	Financial Internal Income Ratio of Whole Investment		8.48%	9.61%
7.2	Capital Financial Internal Income Ratio		11.13%	12.18%
7.3	Investment Recovery PeriodYear		12.59	11.76
7.4	Investment Return Ratio		6.24%	4.22%
7.5	Tax Rate of Investment Return		10.41%	7.03%
7.6	Capital Return Ratio		24.85%	10.60%
8	Financial Standing Index			
8.1	Repay Period of Loan	Year	19	19
8.2	The Highest Asset – Liability Ratio		75.00%	60.00%
8.3	The Lowest Asset – Liability Ratio		2.62%	0.89%
9	Compensation Capacity	yuan/(kW·h)	0.034,7	0.04

5 The comprehensive analysis

It has been listed the contrast analysis for above – mentioned three kinds of compensation schemes in Table 4. The compensation expense of simplex economic compensation scheme is the most with a quite single functional effect; for the engineering compensation scheme of incomplete compensation, the compensation expense is the least with a quite comprehensive functional effect, which can completely compensate the loss of capacity and generated energy of power system, while can simultaneously give attention to compensate the economic loss of hydropower generated energy co., though with a limited compensation ability; for the engineering compensation scheme of complete compensation, the compensation expense is at the middle place compared with those two above – mentioned schemes with the most comprehensive and efficient functional effect, which can completely compensate not only the loss of capacity and generated energy of power system, but also the economic loss of hydropower generated energy co., with an additional produced average annual return after tax of 0.083,2 billion yuan, while otherwise it can drive the local economy development, promote the employment, and achieve the definite economic and social effect, through the construction of thermal power station.

Table 4 The contrast analysis sheet for compensation schemes

Contrast Index	Economic Compensation Scheme	Engineering Compensation Scheme	
		Incomplete	Complete
Compensation Expense	1.580 billion yuan	0.757 billion yuan	0.818 billion yuan
Economic Benefit	None	None	Average annual return after tax of 0.083,2 billion Yuan
Functional Effect	It can completely compensate the economic loss of hydropower station, but cannot compensate its loss of capacity and generated energy	It can compensate the whole loss of capacity and generated energy, but cannot completely compensate the economic loss of hydropower station. It can make a compensation return of 0.034,7 yuan/(kW · h) for lost hydropower station	It can completely not only compensate the whole loss of capacity and generated energy, but also the economic loss of hydropower station, with an additional produced average annual return after tax of 0.083 billion yuan

Summarizing from the above all, it's the most – optimized one to choose the engineering compensation scheme of complete compensation. It suggests to adopt this scheme as the first – choice compensation one for the West Line Works of South – to – north Water Transfer Project towards the influenced hydropower station. On considering that there has been a huge investment for the West Line Works of South – to – north Water Transfer Project, though with an enormous social and environment benefit, its financial benefit is quite low, and from the point of view of decreasing the total engineering investment, it can also adopt the engineering compensation scheme of incomplete compensation as the secondary – choice one. As to the incapable compensation portion in economic loss of hydropower generated energy co., the State can conduct the compensation through come flexible measures (for instance: to deduct or exempt the water resources occupancy expense of constructed works or implement the policy of tax break, etc).

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Study on Urban Water – Supply Modes in the Yellow River Downstream

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Abstract: The water supply system of Yellow River downstream have developed into many kinds of style. According to the work experienced and characteristic of water supply from Yellow river, the author analyzed and summarized the suitable water – supply modes from the place where water intake, the scale of water supply, sediment control, and modes of diversion.
Key words: urban water supply, curve course and circumfluence, the scale of water – supply, sediment control

1 Introduction

"The Project of the RenMin Shengli Channel", which constructed in 1951 opened the history of drawing the lower Yellow River to irrigation. From the 1970s, Henan and Shandong provinces has established more than 70 irrigation areas, developed the irrigated area more than 130 million ha, improved the coast farmland, and promoted the economy and society development. The technology of drawing water to irrigation formed the multiplicate and the mature pattern gradually.

The water volume grows very quickly with the economy development and the population growth of whole Yellow River basin. And the Yellow River downstream resource is actually deficient day by day. And because the groundwater in the lower Yellow River exploit excessively year by year, the water quality worsening is serious. The industry, the domestic water also cannot but rely on the yellow river water resources. So there are many new urban water supply projects in the lower Yellow River in recent years. And the projects also to evolve for many kinds of different pattern like flow automatically water drawing, the pumping station draw water and so on. The author analyzed the development of water supply system and proposed suitable water supply pattern from technical and the economical angles according to the different project characteristic.

2 The urban water supply chacterstic

The urban water supply is different from the irrigation water supply, the characteristics are as follows:

(1) work system, the irrigation water supply is the intermittent work system, and the urban water supply is continuous working system.

(2) water quality, the silt content must be satisfied both irrigation water and urban water, and the domestic water standard also must be satisfied the urban water supply in addition.

(3) Generally, the seal pipeline distance of urban water supply is long. Because most of the riverbed of the Yellow River downstream are higher than the ground outside dike 0.5 ~ 2.5 m, and the Yellow River dike are more than 10.0 m out of the ground . So it is is extremely essential how to send into water factory spaning the Yellow River dike.

(4) Generally the scale of the urban water supply is small, but the water supply guarantee rate is high. So the ability of the project must be strong enough to ensure water supply continual.

3 Choice of the water supply project pattern and its application

3.1 Position choice of the drainage opening

Generally speaking, the position of the drainage opening is chosen approaching the Yellow River main stream, water drawing from the river course side. Construction of xiaolangdi adjust the water volum of Yellow river, in addition, local government in the lower reach supervise the water supply severely, has eliminated the history of zero flow in dry season, make the guranttee without dam for water drawing increased. But because of the characteristic of Yellow River, water drawing without the dam possibly introduces massive silts, causes the ditch deposit, then interferes with the normal work. Therefore, the position choice of the drainage opening plays the decision role in guranteeing water supply and reducing silts. When determining the drainage opening position, we must analyze the geological situation of river bank, the river flood characteristic, the silt content, the river bed evolution in detail, and carry on the technical economy comparison among the reference similar projects.

(1) Water drawing without the dam cannot control change of water level and discharge, so the intake is affected by the water level fluctuation. But the permission design silt content is often surpassed by water drawing water in flood season, the water level and discharge cannot satisfied water drawing discharge request in dry season. In summary, the lacation of the drainage opening should satisfied demand of water drawing and silt control.

(2) Using the principle of curve course and water circumfluence, the place of the water intake will be arranged in the firm and concave river banks. Because the silt content is smaller, and the water depth is enough in the river concave, so the guarantee of water drawing and silt prevention is high. When the intake must be located in the convex shore because of the limit of topographical condition, then the intake gate should be located in the convex shore center point upstream.

(3) When the riverbed is unsteady and mainstream is wandering, the position of the drainage opening should be chosen near the mainstream frequently, and the mainstream morphology change should be observed, and the renovates building should be constructed when necessary.

(4) There are massive for pretecion emban kment in Yellow River downstream. Generally the intake gate is constructed between two groyne dams with the acute angle arrangement for water drawing and silts controlling.

We have both the rich experience and the profound lesson since half century of water drawing from the Yellow River downstream. The project of Dayuzhang in Shandong adopts water drawing without dam. The design discharge is 120 m^3/s, real irrigation is 53 thousand hm^2, and responsible for Shengli oil field water supply. The intake of this project should meet two principle demands according to silt content and unstable river morphology. One is ensuring the discharge needed, the other is solving the problem of silts. Thus 6 schems compared, Wangwangzhuang intake gate is choosed finally. This intake gate is located at 700 m down the concave point. This point has the stable river bed, hard river bank and intense circumfluence, the mainstream of the Yellow River approaches the intake. Considered the Yellow River mainstream change frequently, the water drawing' angle often change along with the mainstream, therefore, chose the water drawing angle is 40° according to the model experiment. This project runs normally since completed in 1956.

The position of water drawing without dam project of Renmin Shengli channel in Henan is selected nearby the Qinchang hydrologic station; opposite of ditch has the mountain mouth which make the intake gate frequently approach the mainstream. But because the river morphology is unstable, the mainstream moves south far away since 1952, sand beach appeared, ditch head only can draw the backwater, which cause intake gate clog with silt, it is difficult for water drawing.

Therefore, the choice of the supply project intake gate position is related to the project opeartion success or failure, must be analyzed synthesisly and dealt with cautiously.

3.2 Scale determination of the Yellow River water supply project

The project scale generally includes the water drawing work scale and the water supply project scale. The water supply scale refers to the water volume that the water factories actually need; the water drawing scale refers to the water volume which actually direct from the Yellow River after considered each kind of factors. The project scale selection must be suitable, oversized creates the waste, excessively small could not achieve the water supply request, affects the production.

Compared with the irrigation diversion works, the scale of urban water supply projects is smaller, but it requests to be able to supply water continuously. But the Yellow River is a sediment high content river. Water drawing from this river request to take measures processing the silt, and assuring the supply project running uninterrupted during silt clear processing period. In the Yellow River flood season, silt content carried by water flow greatly surpasses the permission design, by now the intake gate should be closed. But the water supply project also needs work continuously. In order to resolve this contradiction, increasing discharge and project size are take by most water supply projects. The uncontinuous work system is adopted in the management.

There are no certain rules and data about how much the scale of the water supply project should be expanded. According to statistics, the ratio of water drawing and the pumping discharge can be 1.5 ~ 2 times or 3 ~ 5 times. Generally speaking, the large ratio is adopted in the water supply project of important urban or the extra large enterprise. For example, The Longhu Lake diversion works in Zhengzhou, the scale of water drawing is expanded for 5 times with the rate of 95%. Of course, bigger water drawing discharge, bigger of the matched ditch head building scale, sediment deposite and regulation ability shold be requested, it is no doubt of increasing the investment which should be determined after technology and economy demonstration. The Table 1 is the part data of the water supply projects in Henan Province.

Table 1 The scale of water supply project in the lower Yellow River

Num	Project	Discharge of water supply (m^3/s)	Discharge of water drawing (m^3/s)
1	Water supply project of Mangshan in Zhengzhou	10	16
2	Water supply project in Changyuan county	0.7	5.0
3	Water supply project in Puyang city	1.1	2.2
4	The Longhu Lake diversion works in zhengzhou	1.0	6.0

3.3 The problem of water drawing and regulation

How to solve the relationship of drawing, storing and supplying is the key to solve the contradictory of the water coming and water supplying and the prerequisite to guarantee supply water continuously. Because the sediment coming happened in the flood season, which makes most of the works take measures for avoiding sand peak, it is drawing continuously. Establishment of reservoir with suitable storage and enlarge the regulation ability of water supply not only may solve the contradiction between the interrupted water drawing and continuous supply water, but also may avoid the sand entering the water supply system effectively. The scale of reservoir should be decided after technical economy comparison because it is related to the permission of silt content, peak period of the sand and the establishment of the supply water system. The reservir should be located in the water resource area. Generally the reservoir is located in the flood plain area, because the water quality can be purified further, the silt processing is convenient, the land can be saved then the investment can be reduced.

3.4 Sediment control

The Yellow River is a sediment laden river. Water is drawing from the Yellow River with sand coming. Urban water supplying work demands good water quality, clear water only can go into reservoir, the sediment control must be dealt strictly. Firstly, the location of intake should be resonable, the most common mode is ditch head sedimentation, that is dealing with sediment in the sedimentation pool, which has the obvious sediment effects, has the function of regulation with reservoir.

The silt eigenvalue, namely silt content and silt particle size diameter must be designed firstly when design of silts settling basin. If the silt content design excessively high, the period of the sand be avoided was reduced in the flood season, the water drawing time was lengthened, the deposit silt was increased, then the scale was enlarged or the life was reduced of the silts settling basin. If the silt particle oversized, amounts of silt could suspend in the water, then the water quality could not be satisfied.

Type of sedimentation pond: most of the river beds of the Yellow River downstream are 0.5 ~ 2.5 m higher than the ground outside dike, construction of ssedimentation pond on low – lying land back of the dike may improve the salt alkaloid soil and use silt effectively. For example, the sedimentation pond of the water supply project in Changyuan County was located on the flood plain, using two ditches for sedimentation; Zhengzhou huayuankou water supplying work use the sedimentation pool, after clearing silt with machine periodicity, use again, which is the type of “digging for sedimentation”. Some projects also deposite two times, first is in front of pumping station and second is back of pumping station, Mangshan pumping station is this kind of mode. These typs of dealing with silt may solve the majority of problem, but sand piled up aggravated land desertification, increased the fee of sand moving. Therefore, how to use the silt reasonably will be the important part of water drawing and supplying strategy from the Yellow River.

3.5 The forms of water drawing

There are two forms of water drawing along the Yellow River, one id flow automatically and the other is pumping water. Flow automatically may save the massive energys, reduces the cost, but the discharge is bigger. And pumping water need massive energys, the water supply cost increases, the water drawing discharge is small, but the water drawing guarantee rate is high because the influence of Yellow River is relatively slight.

3.5.1 Flow automatically water drawing

This form is suitable in the area where the water head is high and slope both banks is steep using the is suitable. This kind of water drawing pattern applicate in the irrigation area project is more than in the urban watersupply project.

3.5.2 Pumping water

This pattern is suitable in the area where the water head is low and slope both banks is slow or topography is high. This kind of water drawing pattern is widely used in the urban water supply project. According to different location, pumping water pattern can be divided into:

(1) pumping water and depositing sand: this pattern is used in the work which has no condition of flow automatically (low water head), construction pumping station should be build for pumping water and depositing sand. After sedimentation, flow automatically or pumping water went into water supply system.

Longhu Lake diversion works in East Zhengzhou area belongs to this pattern. Longhu Lake is a large – scale artificial lake. The intake is located near Nanguotou groyne in upstream of Huayuankou, where the flood plain is 4.5 ~ 5.0 m higher than main channel, can not satisfy the water drawing condition of flow automatically. So the design uses the pumping station to draw water, passing through the sedimentation pool and the reservoir, then second pumping station pump clear water into water supply system. This kind of water drawing pattern can not only enhance the water drawing guarantee rate, but also reduce the lifting distance of the second pumping station and the operation fee. This scheme has already been passed the technical and economic appraisal.

(2) Another type of water drawing is the union of flow automatically water drawing and pumped water. This mode is used at the place where the changes of the water head and riverbed are bigger. Usually flow automatically water drawing is used and pumping station used only when the water level drops or the riverbed is undercuted. This type of water drawing can save the massive energy so long

as the management is strengthened. The project in Puyang in Henan province uses a parallel system of a siphon and a pumping station ingeniously. Using the siphon to drawing water when the water level is satisfied to flowing automatically, and the pump is only used as a device filling with water when the siphon starting work. This mode reduce the operation cost greatly.

4 Suggestions

It is the important measures to solve the water resources crisis by constructing the water supply project in the Yellow River downstream. It plays a vital role in economical development of cities. With the development of water supply project in the Yellow River, the modes of water supply also developed unceasingly. According to the actual characteristics of projects, the suitable water supply pattern should be selected:

(1) in the Henan and Shandong area where the discharge is large, intake should approach the mainstream as possible. The mode of flow automatically and silt control at ditch dead is selected so as to save energy .

(2) in the Shandong area where the discharge is small, pumping water and depositing sand at the ditch head should be used to improve the guarantee rate of water drawing and water supply.

(3) in the area where the mainstream is not stable, flow automatically and pump water combination should be used by siphon and pump station, which not only can enhance water drawing guarantee rate, but also save the electrical energy effectively.

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Discussion about the Construction of the Water Quality Security System in Supplying Water with the Yellow River

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Abstract: This article briefly describes the present situation of water quality security of the Yellow River and the problems existing in the construction of the water quality security system in supplying water with the Yellow River. And we also discuss the way and the measures that should be taken from the different views of the government department, the water administrative department controlling the Yellow River and the water providers, in solving the problems existing in the construction of the water quality security system in supplying water with the Yellow River. At last, the opinions about the water quality security in supplying water with the Yellow River are proposed.

Key words: supplying water with the Yellow River, water quality, security, construction of the system

Water is a necessary resource for the survival of our human beings and the development of the whole society, and no other matter can replace it. In some sense, we can say that without water there is no human society today, without the safety of water quality, there is no good health for us all and the social stability and the sustainable development of economics. Water problems have become one of the focal issues of the international community. Water security is calling up the universal attention of the most governments of the world. The water security issues of the Yellow River in our country have also already appeared obviously in recent years.

1 The status and the existing problems of the Yellow River water quality security in supplying water with the Yellow River

As to supplying the people with the Yellow River, we mainly do something in the construction of water facilities, meeting the needs for water, improving the water quality and the level of water supplies. The working focus of the government agencies and water administrative departments are mainly on the supervision of the quality of water supplies, monitoring water quality of industry, and establishing and perfecting the executive branch to the main water monitoring system.

After years of developments on the Yellow River water – supply system, the ability of basic facilities has already met the needs of the industrial and agricultural production and human living along the Yellow River. Aiming at the increase of the serious water pollution and the water quality incident in the Yellow River, the related departments have also set up a system of prevention and have taken all kinds of measures, but there are still many shortcomings and weak links.

1.1 The system of the law and regulations is still not perfect

We still lack the special law and regulations for water quality security of the Yellow River supplies. At present, we still haven't completely built the guard system which is led by the government departments and all related departments and the entire society take part in altogether. Very often it is not paid attention by the government until the terrible problems have appeared. And usually some temporary measures are taken to solve them.

1.2 The Yellow River is facing a serious water environmental challenge

With China's social and economic development and the accelerating urbanization process, the contradiction between water shortage and the water demand is growing increasingly and conspicuously. At the same time, the limited water resources have been facing the serious threat of water pollution. As a result, the water quality security and the water environment in supplying people with the Yellow River water are faced with the great challenge. According to the water pollution investigation for the Yellow River valley, the polluted Yellow River has caused 160 million people in the northwest and north China to suffer injury deeply. Along with the degree enhancement of city industrialization, the pollution along the Yellow River has formed a stern situation in which the "Point" pollutant and the "Non – point" pollutant coexist, and the pollution of living and the industrial emission is in superimposition, each kind of new and old pollution is compounded with twice pollution mutually. The bad result is that the industrial pollutant is polluting the water, and the polluted water is damaging the agricultural ecological environment. Because of the polluted water for irrigation, the production of some local crops along the Yellow River valley has been reduced greatly and even has harvested nothing. In 2004, the people of the Songan village in Jiexiu region of Shanxi Province irrigated their fields with the polluted water in the Fen River; as a result, it caused 200 mu of corn and Chinese white poplar dead. In 2002, nearly hundred mu of wheat were destroyed after the villagers in the Dongzhuang village of Haidong region of Qinghai Province irrigated their wheat with the polluted water in the Huang River.

According to the experts' surveys of the Ministry of Water Conservation and the Yellow River Commission, at present, the agricultural area which is irrigated with the Yellow River water has increased to about 110 million mu. As a result, the water volume of these fields is always 90% of the whole water volume. The foul water flows into the village, and the fields are irrigated with the poisonous water and in the end, the dirty water is drunk by our humans. The water of certain section of the Yellow River has become "the Three Calamities". The people of the downriver are busy with controlling the water pollution, but the people of the upstream are busy with dumping pollutants. The water pollution of the Yellow River not only causes the crops' quality alongside to drop greatly, but also causes some water conservation facilities to be discarded. It is surveyed that the agricultural losses for this pollution are up to 3.3 billion yuan every year.

1.3 Some flaws still exist in the water sources structure

It is demonstrated by some correlative statistics literature that in recent years, with the urgent demand for the Yellow River water source, transferring water over the long – distance range has already become the main solution to solve the problem of water source. Looking from the quantity tendency and the water source structure situation of the Yellow River water supply, we can find that we can't be optimistic on the water resources situation of the Yellow River. The Yellow River is not only faced with the "Resources" lack of the water, but also faced with the "Quality" lack of the water; the usage volume of the Yellow River water resources has broken through the load limit. It is demonstrated by "The Bulletin for the Yellow River water Resources in 2004" which was announced by the Yellow River Conservancy Committee, in 2004, the total volume of the Yellow River water resources was 48.265 billion m^3, and the whole water volume we drew was 44.475 billion m^3. The water resources access rate reaches 92% of the whole water volume having been drawn. Li Guoying, the commissioner of the Yellow River Conservancy Commission, pointed out that excessively usage for water would cause the river to be dry and cut up, and finally it would even cause the river to come to its end.

On one hand, the contradiction of water resources lack in the Yellow River valley is becoming increasingly conspicuous. Since 1972, the Yellow River has run up for 21 years. It is estimated that the total population in the Yellow River valley will come to 121,000,000 and the need for water of the national economy will be 52 billion m^3 in 2010. In the normal years with more water, the water gap of the Yellow River will reach the amount of 4 billion m^3, while in the medium waterless years, the gap will amount to 10 billion m^3. In 2030 and in 2050, the water lack of the Yellow River in normal years will be 11 billion m^3 and 16 billion m^3. The function of the Yellow River's support to the district social economic development will come to its limit. On the other hand, as a result of the overdevelopment and unreasonable utilization of water resources, the problem of the Yellow River's water quality is also extremely serious. Because the volume of the dumped pollutants dropped into the Yellow River is increasing rapidly, it further intensifies the contradiction between the supply and the demands for the Yellow River water resources, and the situation of "Quality" lack will appear in the end.

"The Bulletin for the Yellow River water Resources in 2004" demonstrated that, in the 32 monitor cross – sections of the Yellow River's mainstream, the water quality of 65.6% of the cross – sections is inferior to "The Surface Water Quality Standards" Grade III. And in the 32 monitor cross – sections, water of Grade IV accounts for 40.6%, Grade V accounts for 15.6% and that poorer than the Grade V accounts for 9.4%. It is indicated in some statistics that the direct economic loss which the water pollution of the Yellow River valley causes every year is about 11.5 billion to 15.6 billion yuan.

2 Several suggestions on the construction of safety security system of supplied water quality

2.1 Perfect law and regulations, advocate supervision of public opinion and strengthen supervision and management

Establish the daily water – supplying safety security system and the city water – supplying emergency system, with perfect laws and regulations, legal supervision of every level government and the Yellow River administrative sector, strict management, passive prevention of water – supplying sector, identified function and responsibility and good cooperation of every sector, social public initiative participation, adapting with the economic society level of the development. Further establish and consummate the legal framework of the Yellow River water – supplying safety security system, and make special law referring to the Yellow River water safety, promoting the Yellow River water – supplying safety security management into legal track and manage the water legally.

The public participation is the main content of public management, also is an effective method of dealing with the Yellow River water quality security, so we cannot shield information from the public but need to establish the perfect scientific water quality monitoring system and the truth announcement system. Respect their rights for knowledge of society public, encourage the public to participate in the surveillance, establish the unobstructed information channel, perfect public consults and surveillance mechanism, promptly announce inspection, the monitor, the appraisal result of the product and service and reorganization to the society by a suitable way.

2.2 Government administrative department is the main body of the water – supplying security responsibility

As a result of the Yellow River water – supplying department's monopoly management, the consumers have not the ability of carrying on the quality contrast, so their basic benefit must be performed and protected by the government water – supplying administrative department. Because the water – supplying security relates every common people's life, government water administrative department must carry on effective supervising and managing to this domain in order to guard people's vital interest.

From the government's angle, government has the responsibility to safeguard the public health, and water has special attribute as the public essential item, even if the Yellow River water – supplying takes the implementation water – supplying market reform, the government administrative department still has the final responsibility of cities water – supplying. The water – supplying market reform did not mean that government administrative department can thoroughly get rid of its investment responsibility. On the contrary, the government administrative department must undertake the responsibility which cannot be shirked. Establishing the Yellow River water – supplying water source emergency predetermined plan surely involves projecting investment and water resources redistributes, and this investment belongs to non – management property, which is very difficult to bring into line with the investment income, so it needs the government solve this problem in finance ways like public payment form and so on, manifesting the essential social efficiency in the Yellow River water – supplying.

In the market economy situation, the supervision and management and the construction of the water – supplying safety security system cannot be neglected. Therefore, it is a problem which cannot be avoided that how to enable the emergency predetermined plan obtain finance compensate of the government administrative department.

2.3 Strengthen the water environment control and protection and solve the water resources and quality lacks

As Water Quality security is the life source of the sustainable development, the Yellow River's water environment relates to millions of people's lives. Therefore, it is necessary to further identify the water saving and pollution control. Take "First saving, Controlling as basic, Multi – channel source" as the new strategy of the Yellow River water resource sustainable utilization to promote the positive cycle of the Yellow River water – supplying system. Carry out the synthetic antifouling and reducing strategy of primary source control, move toward the outset in the water environmental pollution control from the terminal, towards the centralism entire life cycle pattern of combining centralization and decentralization from the centralization, toward live harmoniously with the nature in human's survival development idea from the purely demands to the nature. Take restore and repair the destroyed ecosystem as the subject.

There are two main ways of the solution to water resources shortage: first, enhance the water resources using efficiency, and second take the implementation of transferring water from outside to increase the total volume of the Yellow River water resources. The near future goals are that the water – saving irrigating area will attain 64.3% of the Yellow River irrigating area, that the water use factor of the irrigation area will increase from about 0.4 to above 0.5, and that the major and medium city water repetition use factor will increase from the present 40% ~60% to about 75%. The long – way goals are to realize 17 billion m^3 transferring water to the Yellow River through the South – to – North Diversion Water Project in China to optimize the water resources, to guarantee the Yellow River not to cut off, and to provide the guarantee of the water volume and water quality for maintaining the Yellow River healthy life. Enhance and optimize the rivers bearing capacity through increasing and adjusting the Yellow River water volume to achieve the Yellow River overall goal of "The pollution does not exceed the allowed figure".

Taking the water resources protection as the basis is the solution to the water quality shortage. First, increase the water pollution preventing and controlling dynamics, implement the total volume control of the pollutant discharged into the rivers, and reduce the waste sewage withdrawal; second, explore the new ways and the new mechanisms of water pollution prevention and control, and take the way of control pollution jointly. Third, strengthen the scientific management of agricultural cultivation.

2.4 Establish the Yellow River water – supplying water quality safety security mechanism and technique system

The Yellow River water – supplying water quality safety is not a sole department's work, but a social and systematic work. The Yellow River water supply safety security should be established including the emergency organizing system, the emergency predetermined plan system, the emergency pre – warning and the emergency announcing system, information communication and publicizing system, urgent consultation and precautionary measure system, aiding, assistance, treating, curing, rescuing system, legal consequence system and so on to form the persistent effective mechanism.

Establish the Yellow River water – supplying water quality monitoring technical system, and implement the pre – warning monitoring, including sources water monitoring network, water – matching, water – selling various water quality monitor system, realizing the water quality of water source and water – matching real – time monitoring and dispatch management. Using the modern network information technology, realize that water facilities' work long – distance monitoring and supervisory system cover integrity the entire process of the Yellow River water – supplying to promptly gain information from every water – supplying center, providing scientific and reliable decision – making support and guarantee for the Yellow River water – supplying safety security.

Establish the water – supplying security working mechanism. First, establish the information communication mechanism, which can prevent the improper emergency process for the incomprehensive information. Second, establish the department coordinating mechanism, including the coordination between water – supplying department and government water administrative department. Third, establish the cost allocation mechanism. The government organizations, water administrative department, water – supplying department and the public have the responsibility and duty to deal with the coming crisis, and all quarters must have the explicit and common responsibility and expense.

2.5 Strengthen the water pollution prevention measures

Each kind of possible risk factor in water source design should be considered, and the widespread participation mechanism and scientific and democratic policy – making mechanism in the Yellow River water supply project examination and approval must be established, when involves the water – supplying water quality security, a ticket veto should be taken.

Guarantee the extra water supplying ability. Water supplying ability must have certainly pre – supplying, and when water pollution event happens, determine the safety values of the "Guaranteeing the Yellow River not to cut off" and the extra water supplying ability, guarantee a quite big pre – water – supplying ability, fully displays the regulative function of reservoir.

2.6 Make the crisis management plan

From the angle of safeguarding the Yellow River water – supplying security, the water – supplying department should formulate the Yellow River water quality emergency predetermined plan to meet the emergency case or water accident. Carry on the analysis to the water – supplying process, determine the dangerous source, and confirm possible accident type and place, determine the affected scope and the possibly affected people by the accident. Its content must be divided according to the ponderance of accident assessed by the crisis. According to the equipment, the facility or place, the technical process characteristic, identify and analyze the possible accident type, reasons based on the concrete situation. The emergency predetermined plan should conform to the scene and the local objective situation, have the serviceability and the usability, and be easy to operate. The implementation object of the predetermined plan should take the post as a center, but not the concrete personnel, because if the responsibility implementation object is the concrete person in the unit, then when the personnel is taken an adjustment, he can not play his responsible role. Also we must consider the post – accident restoration measures, and the procedure and method of terminating emergency and restoring the normal order and the continuously examining method of the affected regions should be determined clearly.

3 Conclusions

The Yellow River is our "Mother River", and the Yellow River water is the lifeline of the industrial and agricultural production and hundreds of millions people along the Yellow River region. Therefore, the Yellow River water – supplying security is our bounden responsibility. In order to guarantee water – supplying safety, in the work of the Yellow River water – supplying production management, we should positively unify the departments concerned to strengthen the construction of the water – supplying safety emergency system. And we should also grasp the yellow river water quality information accurately and promptly, realize responsibility, guarantee the water – supplying safety, provide the strong security for the further using and protecting of the limited Yellow River water resources and the construction of the harmonious society and the Yellow River sustainable development.

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Analysis of Water Abstracted in the Lower Yellow River

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Abstract: This article analyzed inter - and intra - annual variational characteristics and variational trend, distribution and variational trend in different regions regarding water abstracted from the lower Yellow River; considering preventing the Yellow River breach and satisfying water demand of the lower Yellow River furthest, gave the suggestion on reservoir operation and reasonable water allocation.
Key words: water diversion from the Yellow River, variational characteristics, variational trend, water dispatch, the lower Yellow River

1 Introduction of water abstracted

The Yellow River is the main water source of northwest and North China; the Yellow River downstream is shouldering water supply to four provinces and cities as Henan, Shandong, Tianjin and Hebei. Since inlet sluice of Renminshengli canal in Henan Province was built in 1952, the Yellow River downstream abstraction work has passed through a winding development path. That passed through successively these evolutive phases as exploration attempt, intensive abstraction and irrigation, moderate irrigation for governance, the reorganization for restoring, stable development and, water resource management so on. The Yellow River water abstracted has been not only used in the agricultural irrigation, but also widely used in industry, domestics, ecological environment and many other aspects.

At present, there are 230 water abstraction works in the downstream Yellow River, in which, sluice 117, pumping station and lifting station 110, siphon 3 (there are 55 water abstraction works in Henan, thereinto, sluice 48, pumping station and lifting station 4, siphon 3; there are 175 water abstraction works in Shandong, in which, sluice 69, pumping station and lifting station 106). Designed abstraction volume of water works is 4,047.1 m^3/s (1,283.8 m^3/s in Henan irrigation area, 2,763.3 m^3/s in Shandong irrigation area). The total permission abstraction volume is 10.1 billion m^3 (Henan 3.05 billion m^3, Shandong 7.06 billion m^3). There are 98 irrigation areas in Henan and Shandong of the lower Yellow River. Every irrigation area is over 667 hm^2. The total designed irrigated area is 3,580 thousand hm^2, in which, normal irrigated area 2,450 thousand hm^2, adding irrigated area 1,130 thousand hm^2, efficient irrigated area 2,580 thousand hm^2.

2 Variational characteristics and trend regarding water abstracted from the Yellow River

2.1 Water diversion from the Yellow River grew steadily during 1970s and 1980s, decreased slowly after that, but the proportion that water abstraction occupied water inflow ascended

According to statistics, from 1952 to 2003 cumulative water abstracted from the lower Yellow River was 376.3 billion m^3; the annual average value was 7.24 billion m^3. From 1966 to 1980, the trend of increased and in 1990s decreased (Fig. 1). During 1950s and 1990s, the years' average amount of water abstracted are 3.2 billion m^3, 3.79 billion m^3, 8.12 billion m^3, 10.64 billion m^3, 9.37 billion m^3, respectively, and annual mean amount of water abstracted is 7.85 billion m^3 at the beginning of the 21st century.

Since the beginning of abstracting water from the Yellow River, there has been 52 years. The largest amount of water abstracted from the Yellow River reached 16.7 billion m^3 in 1959; the second largest one was 15.1 billion m^3 in arid 1989. The first water diverting peak in 1959 caused the YR irrigation area salinization and the grain output decreased, but in 1989 the massive diversion played the key role in the resisted the drought, harvest of grain and cotton in the irrigation area. The least annual abstracted water volume is only 0.1 m^3 in 1964 (Fig. 1).

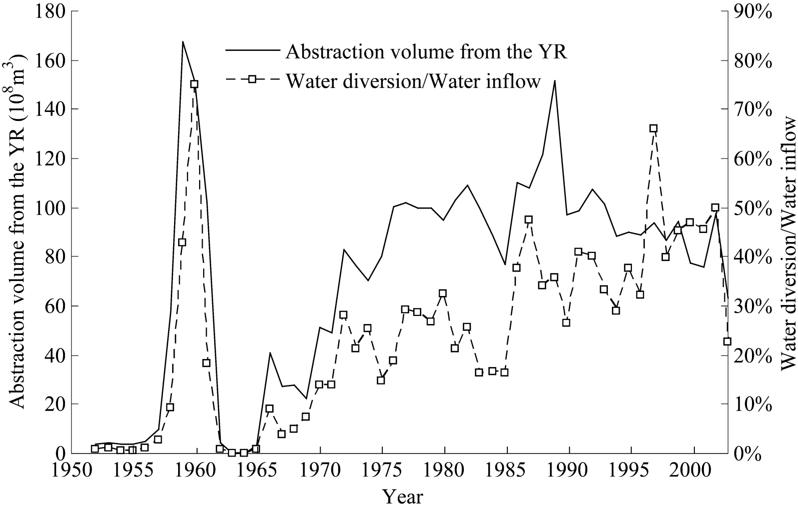

Fig. 1 Yearly change of water diversion from the lower Yellow River

The proportion between the water abstracted and the total water inflow in the lower Yellow River gradually ascended. From 1950s to the early 21st century, the proportion between the abstracted water volume in the Yellow River downstream and the corresponding runoff at Huayuankou station is 6.6%, 7.5%, 21.3%, 25.8%, 36.5%, 39.0% respectively. In 1960 because the volume of water abstracted was high, in addition the Sanmenxia reservoir closes the floodgate and sluicing, the water inflow of downstream reduced, in this year the proportion was the biggest 75%. In 1997 the water inflow was the least; the proportion of that was 66% next below 1960.

In 1970 ~ 1989 the trend of abstraction volume from YR increased progressively year by year, in the downstream Yellow River water volume increased from 5.14 billion m^3 in 1970 to the historical maximum value (15.15 billion m^3 in 1989), growing by twice with the annual average increased rate nearly 6%. Among them, in 1985 ~ 1989, abstracted volume in the downstream increased sharply; and the similar rate of increment can be seen at various sectors. After 1990 abstraction volume decreased gradually, the average yearly abstracted volume was 8.94 billion m^3, decreasing by 0.19 billion m^3 per year, abstraction volume at other sectors of the YR downstream dropped gradually too, besides the Aishan – Luokou sector.

2.2 The profile regarding abstracted volume presented bimodal in the lower Yellow River in a year, most occurrence is in March ~ June; the water abstracted profile tend to be smooth

According to data analysis of 1970 ~ 2003, in the downstream Yellow River water used course liked the shape "M" in a year. The first water used peak (front peak) was in front of flood season during March and May; the second water used peak (peak) was in the flood season during August and September. From 1970s to the beginning of 21st century, the Yellow River water used peak changed slowly; The first water usage peak moved from the May, 1970s to April, 1980s ~ 1990s, and will be still moving up; The latter peak retard from August, 1970s ~ 1980s to September 1990s, and will be still retarding. Since 2000, the peak value has decreased, but the bottom value regarding the water abstracted has increased, therefore, in a year undulation in the water used profile diminished (Fig. 2).

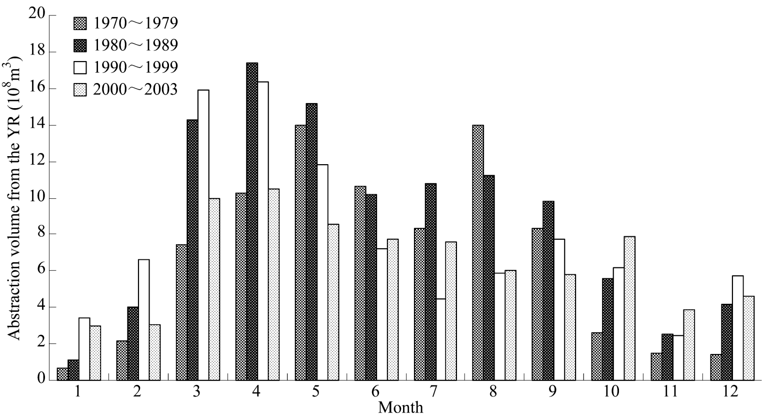

Fig. 2　Distribution of water diversion from the lower YR in a year

In a year the monthly mean water abstraction is 0.767 billion m^3. The most water abstraction is 1.42 billion m^3 in April, accounting for 15.4% of the yearly water abstraction. In January water abstraction is the smallest, only 0.188 m^3, occupying 2.0% of the yearly water abstraction, water abstraction is all above 0.78 billion m^3 during March and September, surpassing the monthly mean water abstraction, but the mean water abstraction surpass 1 billion m^3 during March and May. During March and May the spring irrigation time water abstraction accounts for the whole year 43%, which is the main water used period in a year. From 1970s to 1990s, each month of water used proportion is adjusting slowly: in non - flood season (January ~ April, October ~ December) monthly water used proportion is increasing gradually, but around flood season (May ~ September) water used proportion is reducing gradually. In winter water consumption increases rapidly.

Since 1990, the spring irrigation time during March and May water abstraction has been 3.98 billion m^3, occupying 44.5% of the whole yearly water abstraction, closing a half. Only in April water abstraction has achieved 1.47 billion m^3, accounting for 16.4% of the year, but in March water abstraction obviously has increased to 1.42 billion m^3, closing the April level. In March, April, water abstraction occupied 1/3 of the whole year.

2.3　Intensive challenge between water inflow and water demand in the lower Yellow River

From 1970s to 1990s, the proportion between water abstracted and the inflow in the lower Yellow River dropped at flood season between June and August, in other 9 months of a year, that was in escalation; at the beginning of the 21st century, the proportion undulation that water consumption occupied the water inflow in the lower Yellow River decreased. In March ~ May, 1980s, mean monthly that proportion surpassed 50%. In March ~ May, 1990s, mean monthly that proportion already surpassed 60%, in which that surpassed 67% in April, May. In other words, 2/3 of runoff at Huayuankou station of these two month was diverted by the Yellow River downstream. At the beginning of 21st century, although that proportion of the abstraction peak time dropped, but there was also 4 months (April, May, June, August) in that the proportion that water consumption occupied the water inflow surpass a half, and that period was the crucial phase to preventing the Yellow River breaking (Fig. 3).

Since 2000, although the Yellow River water abstraction has decreased, because of fewer water inflow of the Yellow River, the proportion that water consumption occupied the water inflow linger highly about 47%. In 2003 because of the large dropped water abstraction, the Yellow River water inflow increased to be very much compare recent several years, then the proportion dropped largely to 23%. It has been the minimum value since 1986.

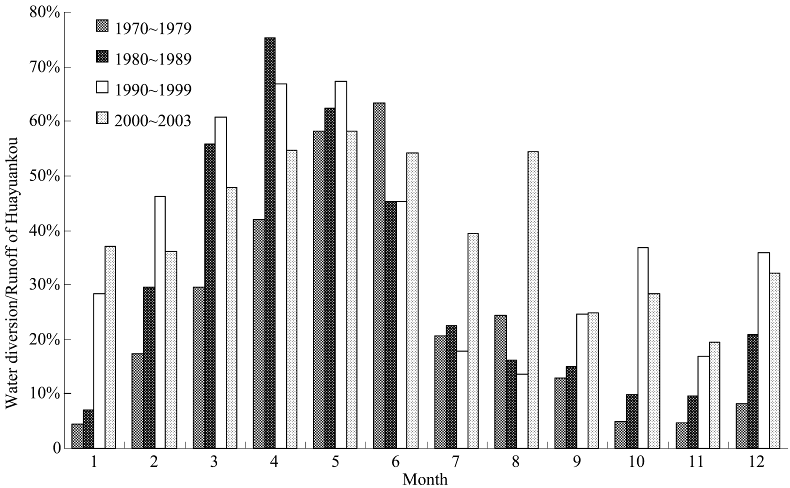

Fig. 3 Diversion/Inflow of the lower Yellow River in a month

3 Variational characteristics and trend regarding water abstracted in different regions

3.1 The regions with higher water abstraction in the lower Yellow River are Henan and Shandong Province, in which, the abstracted water volume in Shandong is over 70%; and water abstraction profile in the two provinces exhibites difference

The main water users of the lower Yellow River are Henan and Shandong Province, they use water in irrigation areas, cities industry and domestic water along the Yellow River. In addition, in recent years, through diverting the Yellow River to Tianjin and Baiyangdian, it made up the water supply insufficiency of region ecology, life, industry and agriculture.

By the abstraction data in Henan and Shandong, from 1970s to the beginning of 21st century, the average amount of water abstraction in Henan fell from 3.28 billion m^3 to 3.01 billion m^3, 2.13 billion m^3, 1.85 billion m^3. In Shandong water abstraction rises from 4.84 billion m^3 to 7.64 billion m^3, 7.34 billion m^3, 5.62 billion m^3. The proportion that water consumption occupied the water inflow in the lower Yellow River in Henan dropped from 40% to 28%, 23%, 24%, in Shandong rised from 60% to 72%, 77%, 72% (Fig. 4). Because of the increasing water abstraction in Shandong, water consumption increased in the lower Yellow River. Owing to durative small water inflow of the Yellow River, along with Yellow River water centralized dispatcher and diverted to Tianjin and Hebei, it would limit water abstraction from the Yellow River to some extent in Henan and especially in Shandong Province.

In Shandong Province each month of water abstraction is bigger than Henan Province, 2 ~ 4 times of Henan generally. In spring irrigation period (March ~ May), each month of water abstraction is respectively 4.4, 7.0, 3.1 times bigger than Henan (Fig. 5). Comparing the Henan Yellow River irrigation areas with the Shandong Yellow River irrigation areas, the precipitation is big in April ~ March and small in May ~ August; in summer planted areas of paddy rice that needs much water are big, therefore, the Yellow River water abstraction is relatively even in spring and summer. In June water abstraction is the biggest. The opposition in Shandong Yellow River irrigation area, the precipitation is few in March ~ April and much in May ~ August; the paddy rice planted areas are small, therefore, the water consumption concentrates in March ~ May; the biggest water abstraction is in April. Differences of water used process between Henan and Shandong is advantageous in the adjustment of Yellow River water abstraction in the lower Yellow River.

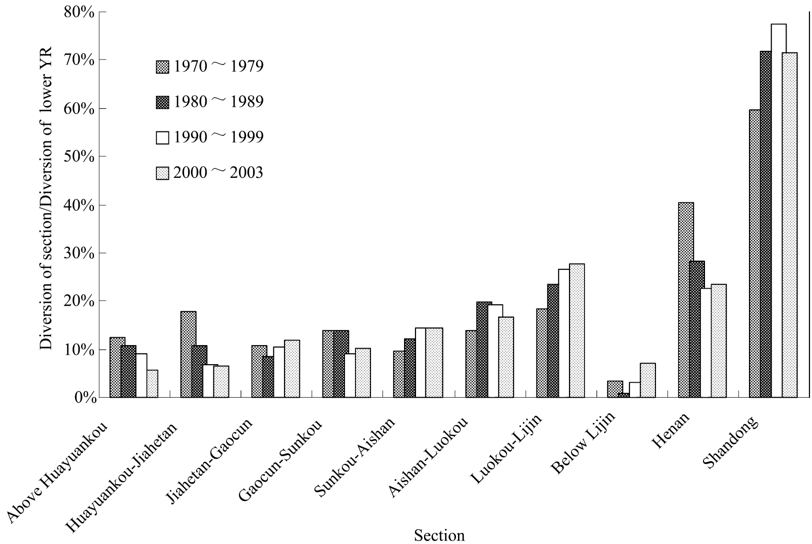

Fig. 4 Diversion proportions of different sections in the lower

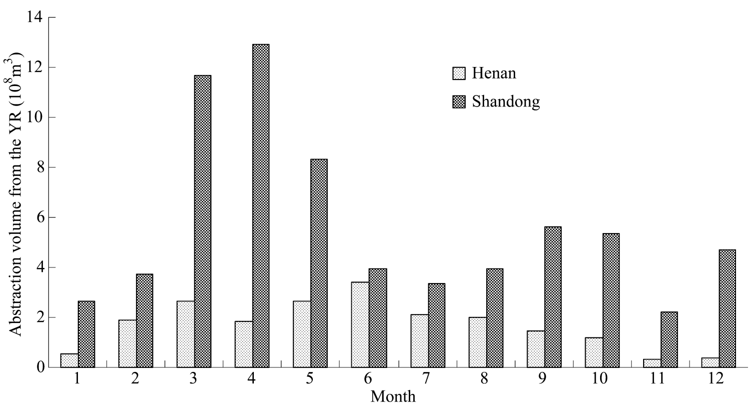

Fig. 5 Water used process of Henan and Shandong Province in a year

Since 1972, in order to alleviate short of water in Tianjin and Hebei, through Renminshengli canal of Henan Province, diversion sluices of Shandong Weishan and Panzhuang irrigation area, it has successively diverted Yellow River water to Tianjin. To January, 2003, there has been carried on 5 times diversion altogether to Tianjin; the accumulation of Yellow River water abstraction achieved 3.88 billion m^3, accounting for 1.3% of the total water abstraction in the lower Yellow River contemporaneously.

3.2 Abstraction is degressive in most of reaches, but different reaches presents different variational profile

Inview of the section water abstraction, at upper - section of Huayuankou, Huayuankou - Jiahetan section, Jiahetan - Gaocun section, Gaocun - Sunkou section, Sunkou - Aishan section, Aishan - Luokou section, Luokou - Lijin section, lower - section of Lichin of Yellow River, multi - annual mean water abstraction respectively are 0.945 billion m^3, 1.012 billion m^3, 0.916 billion m^3, 1.111 billion m^3, 1.15 billion m^3, 1.633 billion m^3, 2.176 billion m^3, 0.255 billion m^3, occupying total water abstraction of the lower Yellow River 10%, 11%, 10%, 12%, 12%, 18%, 24%, 3% respectively. The biggest water abstraction is at Luokou – Lijin section, the smallest is at lower – section of Lichin (Fig. 6). Except the smallest, other reaches' water abstraction are all in dropping trend.

From 1970s to the beginning of the 21st century, proportion that various reaches water abstraction occupied total water abstraction of the lower Yellow River assumed slow variational trends. Threreinto, at upper – section of Huayuankou and Huanyuankou – Jiahetan section, the proportion assumed falling trends; at Sunkou – Aishan and Luokou – Lijin sections, the proportion assumed trend of escalation; at Jiahetan – Gaocun sections, Gaocun – Sunkou sections and lower – section of Lichin, the proportion assumed the trend that fell first and rising afterward; at Aishan – Luokou section, the proportion assume the trend that rose first and falling afterward (Fig. 4).

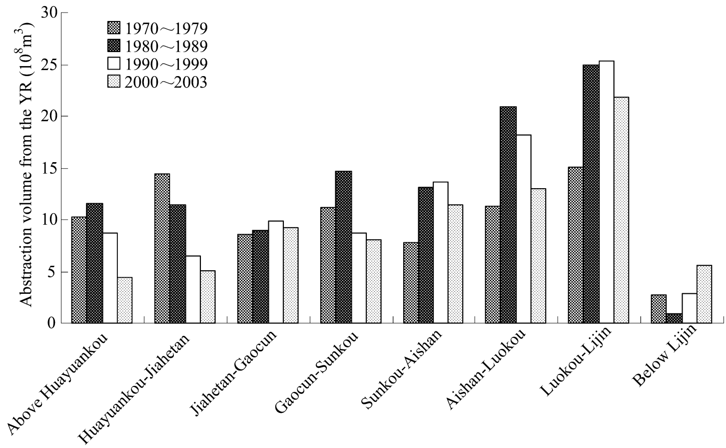

Fig. 6 Water diversion of sections in the lower Yellow River

4 Usage of water abstracted from the Yellow River

Since the beginning of water diversion from the lower Yellow River, the Yellow River played the vital role in boosting local agriculture and industrial development, improving environment of irrigation area and so on.

In 1950s that was the attempt time of water diversion from the Yellow River, water abstraction mainly used in silt depression, irrigation, saline and alkali land improvement and drinking water of partial area. In the blind period of development, water abstraction mainly used in irrigation and storing water. In restoring and stable period of development, water abstraction mainly used in irrigation, sediment ejection, soil alteration, transformation of salt alkaloid and sandy waste in the irrigation area and so on. In the near past, except used in irrigation, the Yellow River water abstraction was also diverted to water source area to supply groundwater, and used gradually in industry, human and livestock drinking water, aquaculture and so on, especially transported to Tianjin and Hebei's on a big scale in winter. According to statistics on water consumption of Henan and Shandong irrigation area, in all water abstraction, water consumption in agricultural occupied 93.6%; water consumption in industrial accounted for 4.9%; the human and livestock water consumption accounted for 1.0%; the fishery and other waters consumption accounted for 0.5%.

Since the implement of intergrated distribution of water in the Yellow River, because of science distribution, rational distribution, it completely changed the blindness of the Yellow River dostinstream diversion, safeguarded city and countryside lives of the people water used in the lower

Yellow River, powerfully supported the down stream area drought – fighting work, arranged the agricultural water used reasonably, given dual attention to the industrial water use, in particular through the reasonable dispatch and water used planning, frugal water used of along the Yellow River provinces and areas, enhancement surveillance inspection, in the great drought year it maintained the Yellow River Lijin station not to be blocked the flow, reversing the position of block the flow seriously Since 1990s. Simultaneously through diverting the Yellow River to Tianjin and Baiyangdian, it made up the water supply insufficiency of region ecology, life, industry and agriculture production, exerting water use value of the Yellow River fully.

5 Suggestions

the downstream Yellow River is shouldering water supply for four provinces and cities as Henan, Shandong, Tianjin and Hebei; With the water resources allocation in the Yellow River basin since 1990s, the downstream Yellow River has seen the drop tendency regarding water abstraction, but because the inflow in the downstream Yellow River decreases, the water abstracted still accounts for the total water volume about 40% , prevented the Yellow River will block the flow cannot lower one's guard, annual March ~ June, the monthly amount of water diversion will account for the same month to come the water volume in particular the proportion to surpass or close 50% , will be prevented the Yellow River will block the flow the crucial phase, will be supposed to enlarge the excreted water of Xiaolangdi reservoir, reducing the risk of the Yellow River breach in critical period.

The water abstraction in Shandong irrigation area occupies over 70% of the total in the lower Yellow River. This area is the biggest water users of the lower Yellow River, so it should act according to the differences in precipitations and water consumptions between Henan and Shandong Province in a year, enlarging water assignment of March ~ June in Shandong. Through rational distribution, dispatching Yellow River water abstraction of two provinces, that will satisfy water requirement of the two provinces furthest.

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Thinking of "Two Kinds of Water Supplied Separately and Two Kinds of Charges Measured Separately"

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Abstract: According to national policies, the price of water resources varies in terms of the time and usage of water supply of the Yellow River, and the difference becomes bigger and bigger. The implementation of "two kinds of water supplied separately and two kinds of charges measured separately" is an important measure to keep the water with the water, which is of great significance for the optimal disposition of water resources, the efficient saving and utilization of water resources, and the harmony between human being and the Yellow River. This article analyzes the necessities of "two kinds of water supplied separately and two kinds of charges measured separately", summaries some problems of the implementation, and discusses how to carry out this task.

Key words: water resources of the Yellow River, two kinds of water supplied separately, keep the water with the water

1 Introduction

"Two kinds of water" refers to the water used for agriculture and nonagriculture. The agricultural water mainly includes the water used for irrigation, feeding and drinking in the countryside etc. The nonagricultural water refers to the water used except for agriculture, and mainly includes water used for industry, life and ecological landscape etc. "Two kinds of water supplied separately" refers to the agricultural water and the nonagricultural water which are used separately at different times in the same channel system of the Yellow River. Generally, the agricultural water is preferentially supplied during the farming season, and the nonagricultural water is supplied during other seasons. "Two kinds of charges measured separately" means to define scientificlly the difference between the agricultural water and the nonagricultural water, in terms of the improvement of the measures and management patterns.

2 The necessities of the implementation of "two kinds of water supplied separately and two kinds of charges measured separately"

Water resources are important and strategic resources for the economic and social development. Along with the agricultural and industrial development in the Yellow River Basin and the improvement of people's living standard, the conflict between water demand and water supply becomes more significant, and the water crisis is also more widening. The implementation of "two kinds of water supplied separately and two kinds of charges measured separately" is of great significant for the optimal disposition of water resources, the efficient saving and utilization of water resources, the support for the central agricultural policy, the harmony between human being and the Yellow River, and the maintenance of the Yellow River's healthy life.

2.1 The advantages for the efficient saving and utilization of the Yellow River's water

As an important water source in Northwestern China and Northern China, the Yellow River supplies water for 0.14 billion people, 0.16 million km^2 cultivated land, more than 50 cities in larger or middle scales, the energy bases and the oil fields within the basin and along the lower reaches of the Yellow River. Moreover, the Yellow River also supplies water for those cities or regions beyond the basin, such as Qingdao, Tianjin etc., which are very far away from the Yellow

River. At present, water demand exceeds the carrying capability of water resources of the Yellow River. Zero flow has been more frequent since 1970, which causes great loss for agricultural and industrial economy, and also makes our survival environment worse. This situation was shocking especially in1997, in which zero flow lasted for 214 days at Lijin station. Since 1999, with the unified regulation of water rescources and the success operation of the Xiaolangdi Reservoir, the flow hasn't been broken in the Yellow River during the following seven successive years. However, in recent years, the inflow tends to be dried up, and the discharge of the river reduces annually. Accordingly, the available water resources can't meet the rapid increase of water demand. Now, the conflict between water demand and water supply is sharpening. At the same time, the understanding of saving water is very weak. For example, agricultural water is wasted seriously due to traditional irrigation approaches, such as flood irrigation etc.; water resources are lossed along the channel due to the lack of matched facilities in the irrigation region. According to some statistics data, the irrigation utilization coefficient is about 0.45 in our countryside, while it reaches 0.8 in those developed countries. There is still big gap to save water resources in China. In the past years, the confusion of agricultural water use and nonagricultural water use, leads to the increasing waste of nonagricultural water. The implementation of "two kinds of water supplied separately and two kinds of charges measured separately" is the basic approach to solve the shortage and the waste of water resources. By agricultural water supply at different times and the plan index of water quantity, the invest in agriculture are relatively increased, the matched facilities is relatively perfected, and the efficiency of water use is also enhanced. Therefore, the saving of water resources can be realized. Due to the higher price of nonagricultural water, and the strengthening management and the exact measure of water quantity, and the economic lever ect., the water users with larger water waste could realize the importance of water resource again, and think of water resources on basis of its production cost. Thus, the water resources could be saved efficiently.

2.2 The advantages fot the harmonious new order of water supply

The present facilities of water supply are mainly developed from the channel system of farming irrigation. When water resources can't meet the demand of the citilization, the industrilization and living standard, nonagricultural water is supplied indirectily by the farming irrigation region. Usually, the mixture of two kinds of water supplies in irrigation season, makes it difficult to measure each kind of water quantity. Because water users for industry and living standard are mostly located at the end of irrigation region, nonagricultural water can be met by occupying a lot of agricultural water, and its water loss is quite striking. Consequently, it's impossible to meet the demand of agricultural water at the exact time. Then, the farmer's benefits can't be guaranteed, the economy becomes more fragile in the countryside, and the conflict between demand and supply is more serious. The implementation of "two kinds of water supplied separately and two kinds of charges measured separately" can solve the problem efficiently to some extents. During the peak time of agricultural irrigation, water should be supplied to farming preferentially. Water supply for industry and living standard should be carried out with plenty of water or good quality during flood season or in the winter. The reservoirs in the plains, the watercourses and the pools should be used fully to store water resources of the Yellow River as much as possible. Then, the passive situation of water conflict could be changed during the peak time of agricultural irrigation, and the harmonious new order of water supply is builded. All these can efficiently prevent zero flow in the Yellow River, realize the maintenance of the Yellow River's healthy life, promote the harmony between human being and the Yellow River, and sustain the development of industry and agriculture by permanent utilization of water resources of the Yellow River.

2.3 The advantages for the extension of management of water supply and the optimization of industry structure

The 11th "five – years – plan" is an important period to generally build the wealthy society. The continuous rapid development of national economy needs the support of water resources. As the management department of the Yellow River, it's our duty and mission to supply water resources of the Yellow River. At the same time, water supply of the Yellow River is not only an important economic support in the Yellow River basin, but also an important approach to keep water with water. Because of the limited water resources of the Yellow River and the increasing water demand in the industry and agriculture, the pattern of management and operation of water supply should be altered. "two kinds of water supplied separately and two kinds of charges measured separately" should be implemented, the saving of agricultural water should be advocated, and the persentage of nonagricultural water should be increased. Based on the stable quantity of total water supply, the optimization of the structure of water supply, the extension of the industry chain and the change of the pattern of water supply, not only improve the efficiency of water use, but also provide a strong economic security for the sustainable development of water supply.

2.4 The advantages for the support of the central agricultural policy

"Two kinds of water supplied separately and two kinds of charges measured separately" is a new measure to manage water resources of the Yellow River, with the policies of "Three kinds of Agricultures" and "The construction of new socialism country". The Yellow River Department won't affect agricultural water use in spite of more expensive price of nonagricultural water. On the contrary, this department will supply irrigation water preferentially during the peak time, and guarantee water demand of agriculture water and the farmer's benefits. "Two kinds of water supplied separately" only makes use of the larger storage capability of the reservoir in the plain, supplies water resources at different time, fully exert the role of a group of reservoirs, and regulates the discharge and the inflow of the Yellow River. It is an effective approach of water supply to solve the long – term conflict between agricultural water use and industrial water use, to optimize and utilize the limited water resources of the Yellow River scientifically, and to realize the maximum benefits of economy. This not only embodies the implementation of the construction of new socialism country by the Yellow River Department, but also provides a new approach for the disposal and management of water supply of the Yellow River.

3 Problems on the implementation of "Two kinds of water supplied separately two kinds of charges measured separately"

"Two kinds of water supplied separately and two kinds of charges measured separately" is a new approach for the water supply of the Yellow River, and also is an innovation to traditional approaches. The success implementation is related with the problem between water supply and economic benefits, also is linked with the harmony between the harness of the Yellow River and the development environment. The implementation of this policy will break up the traditional pattern of productiion and management, so it is unavoidable for the difficulties, new problems and new conflicts.

3.1 Wrong understanding of agricultural water by a few of water users after the adjustment of price

In Nov. 2001, Commodity Prices Bureau in Shandong Province transmitted a document of "Information on the adjustment of water price supplied to the Initial Part of Project in the lower reaches of the Yellow River" from State Development Planning Commission. It decided that since 1st Dec., new price of water supply is implemented at the Initial Part of Project in the lower reaches of the Yellow River. It is the first time for the prices of agricultural water and nonagricultural water to be different. In 4th April, 2005, another document from central government increased nonagricultural water price again, but didn't change agricultural price. Then the difference between agricultural water price and nonagricultural water price is increased further. For individual interests, some illegal water users of agricultural water take up or steal agricultural water, and seriously disturb the normal order of water supply.

3.2 The difficulty of management of water supply using the same channel by agricultural water and nonagricultural water

In the past years, the model is "To manage the initial part of channel but not the whole channel, and to manage water supply but not the uses". Agricultural water and nonagricultural water is transported in the same channel. And water quantity of agricultural and nonagricultral water is measured by the unscientific and unreasonable fixed ratios. This is easy to be managed, but the taking – up of agricultural water by lots of nonagricultural water, not only causes the great loss of water resources and the lack of agricultural irrigation, but also influences the economic income of the department of water supply. After the implementation of "two kinds of water supplied separately and two kinds of charges measured separately", the department of water supply must take part in the supervision and the management of nonagricultural reservoir, prevent water utilization altered. Actually, this is difficult to be carried out by the department of water supply.

3.3 The lag of discharge measure and the lower accuracy of measure

At present, traditional facilities are mostly applied to measure the discharges at water gates of the Yellow River with less frequency of measure, big error, artificial factors and less acuracy. Although the long – distance monitor system was constructed at the water gate of initial part of channel, it is impossible to completely realize the automotic measure of the discharge. The measure of nonagricultural water is more outdated with incorrect data and serious error. Finally, this results in the conflict between the water uses and water suppliers.

4 How to carry out "Two kinds of water supplied separately two kinds of charges measured separately"

"Two kinds of water supplied separately and two kinds of charges measured separately" is an important innovation to traditional management pattern of water supply. In spite of the heavy difficulty, the complex situation, and the acute conflict, new ideas and further research will bring the solutions to new problems.

4.1 Strengthening propaganda, communicating actively and building healthy background of water supply

The Yellow River is short of water resources, and its conflict between water demand and water supply is very outstanding. The water utilization in the lower reaches is complemently resulted from the integrated regulation of water resources of the Yellow River. "Two kinds of water supplied separately and two kinds of charges measured separately" concerns directly the interests of both water users and water suppliers. However, all levels of goverments and water users department can't fully understand the management of water resources of the Yellow River. This increases the difficulty of implementation and the the levy of water charges.

As for these problems, water suppliers and water users should communicate actively with each other. On the other hand, the importance and necessities of water conflict and water regulation of water resources of the Yellow River should be greatly propagandized in order to realize the understanding of "each drop of water is precious" by goverments and water users, such as the achievement of the harness of the Yelllow River during the past 60 years, and the achievement after water regulation etc.

"Two kinds of water supplied separately two kinds of charges measured separately" is necessary for the permit of water supply from the Yellow River and the policy of water price. It can protect the demand of agricultural irrigation and farmer's interests, and support the development of agriculture and the construction of new countryside. It can also exert the role of economic level of water price and strengthen the consciousness of water saving by the public and especially the factories and mines enterprises. And it can exert the regulation of reserviors, save the cost of investment and the land resources. By propagandizing it greatly and analyzing its advantage and disadvantage, understanding, support and cooperation could be gained by the governments and water users. Therefore, good environment is established for the implementation of "Two kinds of water supplied separately two kinds of charges measured separately".

4.2 Further research, extending the management of water supply and preventing the gaps

On basis of deep investigation, the feature of water use should be defined scientifically. The department of water supply department should investigate the water demand, the potential water demand, the storage and utilization of water resources, the capability of water supply and the trendency of development of water supply etc. And these departments also should grasp the irrigation region, water demand and the first – hand data of water uesers so as to separate nonargicultural water. At the same time, the supervision and inspection should be strengthened for the correct and reliable data of water supply. The implementation of "Two kinds of water supplied separately and two kinds of charges measured separately" is the extension of the management of water supply from a line to a region. Accordingly, the traditional management of water supply should be adjusted, and the supervision of water supply should be improved. The supervision and inspection should be carried out day and night, so that "running, emitting, dropping, leaking " of water resources, and the taking – up agricultrual water by nonagricultural water could be avoided. Whether agricultural water is acturally used in agricultral irrigation should be traced and checked. By the extension of management of water supply, the implementation of all the supervision mentioned above, and the strict separation of water utilization could ensure the accurate quality and quantity of "Two kinds of water supplied seperately".

4.3 Improving the measures and measuring correctly

The research on discharge measure should be strenghtened. The automatic exact discharge measure is key to lessen water loss and realize the science regulation of water resourses of the Yellow River. The discharge measure should be paid more attention and invested properly. For the water gates at the initial part of channel, the online discharge measure should be put into practice as soon as possible so as to reduce the error by traditional measure approach and artificial factors, using the long – distance monitor system. For water gates with more nonagricultural water use and the possibility of installing long – distance measure of water quantity, monitor system should be invested and installed soonly to realize long – distance mornitor and automatic discharge measure and to obtain the correct, prompt and reliable data of discharge measure. And it is possible to reduce the by – incorrect measure of water quantity between water users and water suppliers.

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Research of the Yellow River Sluice Water Supply Measuring Facilities

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Abstract: It is urgent to improve the discharge measuring accuracy of the sluice and the precision of the water supply discharge, because of the serious shortage of the water resources and the increasing contradiction between water supply and demand in the Yellow River. We introduce single chip microcontroller technique and converter technique into the original system and get a new type GSLLCY – 1 discharge measurement and digital processing system . The maneuverability and reliability of lead fish are improved during the practical using on the sluice, as well as the automation degree of the discharge measuring is improved and the measuring time is shorten. Meanwhile, the workload of the technicians is decreased and the work efficiency and the quality of the measurement's result are improved a lot.

Key words: discharge measuring, digital processing, development

1 Preface

At present, more and more attentation are paid on the improvement of the discharge measurement accuracy of the sluice and the precision of water supply discharge, because of the serious shortage of the water resources and the increasing contradiction between water supply and demand in the Yellow River. The improvement of the measuring accuracy and practicality is an important research which should be investigated as soon as possible, with the development of automatization and modernization of discharge measuring. The investigation of the fast and accurate discharge measuring and the development of the digital processing system can not only provide the reliable hydrologic data for the water supply in the Yellow River, but also is great meaningful for the management and distribution of the water resources in the downstream Yellow River.

2 The necessity of the construction of canal hydrologic cableway

At present, there are some defects in the cableway system that used by the Yellow River water supply sluice discharge measurement: firstly, the control of the horizontal and vertical motion of the lead fish is insecure, and the lead fish is usually uncontrollable, and the speed control is unsteady. So this method of speed control has already fell into disuse; secondly, the measurement of the data of distance from initial point, depth and current velocity relies on manual work or mechanism, so the data are unreliable and can not be recognized by computers, let alone computer sampling data automatically; thirdly, the calculation of discharge is done by manual work with high mental labor load.. Therefore it is necessary to develop a new hydrologic cableway to measure the discharge of canal with high measuring accuracy, high automatization degree. The new hydrologic cableway is equipped with a totally new current meter, which is designed with the latest technology, material and method, and this enables it to supply with immediate and accurate hydrologic data of the Yellow River. The new system will serve for distributing the water resources in the downstream Yellow River, and will also serve agriculture, industry and daily life of the people along the river.

3 The feasibility of the construction of canal hydrologic cableway

The key techniques which will be used in the new system: ① frequency conversion speed control technique; ② telecommunication technique; ③ single chip microcontroller technique;

④automation technique.

Frequency conversion device have already been widely used in all walks of life. It is convenient to control the speed of an electromotor with a frequency conversion device, which have the best control capability among all the electric control equipments, and have been widely used on canal hydrologic cableway. The thyristor speed control technique and electromagnetism speed control technique have already been fell into disuse due to their own defects.

During measuring, the current velocity data, water surface signals, and the signals from the bottom of the river are transmitted to the operation room, and are directly collected by the equipments. The original way of receiving and processing signals is thoroughly abandoned. Thus the discharge can be measured automatically. But there is still a problem of information transmit . At present ,people usually use wire and radio transmission, but they both have their own defects . The reliability of wire transmission is bad ,but its signals' integrity is very good; the capability of the radio transmission is good and reliable ,but its circuit is complicated. Here we adopted wire transmission combined with radio transmission to transmit signals. The signals are transmitted through cables from the bottom of the river to the travelling cranes above the water, and from water surface to the operation room by radio transmission.

The control cabinet is equipped with intelligent bathometers, intelligent speedometers, and intelligent measure equipment of distance from initial point. The water depth, current velocity and distance from initial point are displayed directly on the screen and transmitted to computers through interface circuits. Each of the three digital meters has a core of single chip microcontroller, so their capability is steady, and it is easy to operate them.

4 The development research of the system

4.1 The hydrologic characteristics of canal

The characteristics of canal are as follows: the measuring cross section is narrow and is usually about 100 m in the width; the current velocity is low and the space – time distribution is even; the depth of water is small; the measuring cross section is generally within 500 m away from the sluice downriver or upriver, and the bottom of the channel is sandy riverbed with a relatively high rigidity the discharge of the channel is usually no more than 100 m^3/s.

4.2 The design of the system

The integral parts of the whole system are as follows: ①operation room; ②cableway structure system; ③circulation system; ④frequency conversion speed control comprehensive control cabinet; ⑤travelling crane; ⑥ lead fish; ⑦ data collecting and discharge computing system. (The arrangement of the cableway is shown in Fig. 1)

The operation room: the room is used to fit the hydrographic winch, the comprehensive control cabinet and the right bracket of the hydrographic cableway (the right bracket is fitted in the operation room). The operation room is the original one for the sake of the lack of money.

The cableway: for the reason of lack of money, the brackets are not replaced, but the ropes are changed into type Φ 9 wire ropes.

The circulation system: the circulation system is comprised of the hydrologic winch, the circulation wheel, the circulation rope and the balance weight etc.. The hydrologic winch is still the original one, but equiped with a point probe (sensor) to measure the distance from initial and a depth probe (sensor). The circulation wheel is equipped according to the actual demand.

The frequency conversion speed control comprehensive control cabinet: the control cabinet consists of frequency conversion device, control circuit, signal receiving and processing circuit, intelligent bathometer, intelligent speedometer and intelligent measuring equipment of distance from initial point.

The travelling crane: the traveling crane consists of radio signal transmitter and moving components. The current velocity signals, surface signals and signals from the bottom of the river

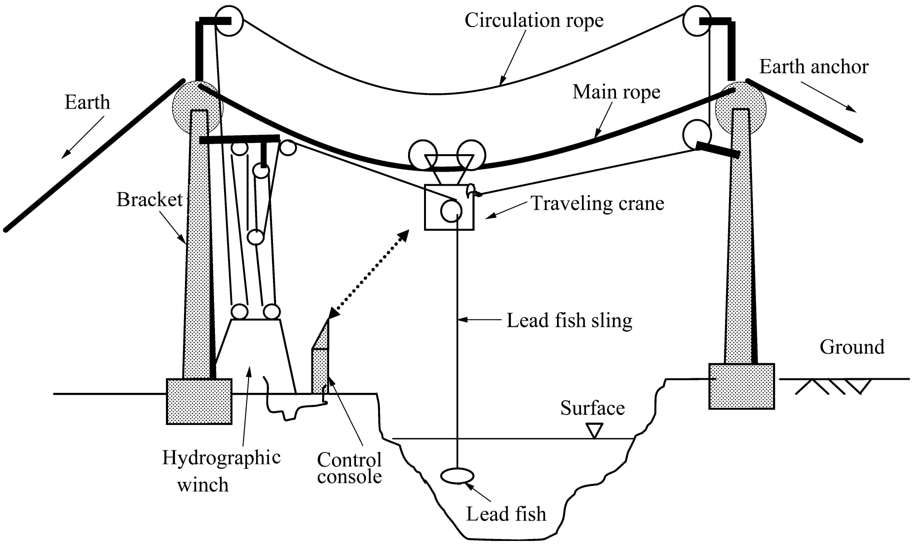

Fig. 1 Sketch of cableway layout

are transmitted through cables to the transmitter, and there they are coded by the transmitter, and then the signals are modulated and transmitted wirelessly to the operation room.

The lead fish: For the sake of the convenience of measuring the channel, the lead fish is the original one, but a depth sensor is fitted to it.

The discharge computing system: The discharge computing system consists of laptop, printer, and discharge measurement processing program. The control console has data interfaces in order to calculate the discharge directly with computers.

4.3 The main parts of the system

(1) The main body of the cross – river cableway: it consists of the main rope, the brackets and the earth anchors

(2) Operation room: it is the place where the winch and the control console are fitted.

(3) Control console: it is the control centre of the horizontal and vertical motion of the lead fish, and it is the core of the whole system. ①It is used to control the motion of the lead fish – forward, backward, upward and downward, and it can also carry out stepless speed regulation. ②It can carry out intelligence control on the lead fish through the control of its motion. ③It has also been equipped with intelligent bathometers, intelligent speedometers, and intelligent measure equipment of distance from initial point, and it is the prepositive instrument of data collecting, and is the core part to collect data directly.

(4) The circulation system: it consists of the hydrographic winch, the circulation wheel, the circulation rope, the balance weight and the travelling crane etc..

(5) Signal system: the signal system consists of current velocity signals ,surface signal , and signals from the bottom of the river as well as the transmitting and receiving instruments of these signals etc. There are four kinds of limiting position signals – forward limiting position signals, backward limiting position signals, upward limiting position signals and downward limiting position signals. The four kinds of signals are transmitted to the control console, and the control console gives out stopping control in.

(6) The discharge data processing system: it is made up of discharge computing program, computer (portable power supply), and printer.

4.4 Operation method of the system

4.4.1 Initial setup

Open the main program and you will get into the main interface, then open the "parameters setting" menu to do the initial setup. None of the parameters can be omitted, and the setup can be done only by specialized technician (password protection).

4.4.2 The hydrologic measurement

Choose discharge measurement according to the requirement, and then you will get into the data inputting interface. First of all, fill in the head of the table according to the recording order (pay attention to what you are going to do, to measure or to check), then choose a current meter and a formula and begin to record data.

Make sure to click "survey point" and the "vertical average" each time the data of a vertical has been totally recorded, otherwise the computer won't calculate them. Then save the measurement result and turn to the next vertical until all the verticals have been recorded.

Start to fill in the measurement information when the measurement is finished (some unnecessary items can be omitted), then click "measurement information" and choose "save". At last click "close" and choose "save" to end the measurement. (The computation won't go on if the measurement information hasn't been filled in or saved).

4.4.3 Data modification

If you find the origin input data are wrong, you can use this option, or it can be used during the repetition measurement of the vertical velocity. Take care when you use "delete data of this measurement", or you will lose all the measured data.

4.4.4 Annex data

This option is used when verticals are lost or need to be supplemented during the checkout.

4.4.5 Print

This option is used to print the results, and the printing mode is single page print. Due to the differences between operating systems, it may need to do some setup, and each station can set based on their own situation. In the Windows2000/XP system, if the page deviates, please modify paper page setup to A4 landscape, in the advanced options of printer setup.

5 The comparison of actual measurement

5.1 The measured discharge comparison under different discharge degree

We carried out 34 times of measuring experiment under different discharge degree with the new type GSLLCY – 1 discharge measurement and digital processing system and the original system, and compared the results. The maximum measured discharge is 32.5 m^3/s, and the minimum is 8.30 m^3/s; the maximum relative deviation is 5.38%, and the minimum relative deviation is 0.31%. Through statistics analysis we know that, the systematic error is 0.03%, the incidental error under 75% accumulative frequency is ±2.98%, and the incidental error under 95% accumulative frequency is ±4.10%. The error of either system is within prescribed limit (the prescribed incidental error is ±5%)

From actual measured discharge by the new and original system we can see that all the measured discharge are around the 45°line, and this is close to the actual discharge. This indicates that the actual measured discharge of the new and original system are both close to actual discharge.

5.2 The measured discharge comparison under the same discharge degree

We chose three kinds of opening state and carried on 30 times of experiments under the same opening state. We can see from the results that in the new system, the actual discharge fluctuated around the axes of 16.5 m^3/s, 35.4 m^3/s, 27.6 m^3/s under the three kinds of opening state. The maximum amplitude is ±2.5%, and the minimum amplitude is 1.1%, and they are all within ±5%, which is the prescribed limit; in the original system, the actual discharge fluctuated around the axes of 16.6 m^3/s, 35.4 m^3/s, 27.7 m^3/s under the three kinds of opening state. The maximum amplitude is ±2.9%, and the minimum amplitude is 0.6%, and they are all within the prescribed limit too.

Through statistical analysis we can see that the systematic error is 0% and the incidental error under 75% accumulative frequencies is ±2.00%, and the incidental error under 95% accumulative frequency is ±3.14%. The error of either system is within prescribed limit (the prescribed incidental error is ±5%). The results are shown in the following table.

From the results of the comparison and the actual measured discharge by the new and original system we can see that the discharge varying amplitude of the original system is bigger than the new one. This indicates that the incidental error of the original system is bigger than the new one and the accuracy of the new system is relatively high and is closer to practicality.

5.3 The comparison of the measurement of the width of water surface and the water depth

The mode of comparison: The measuring ship is used to measure the width and the water depth in standing waters, and the new system is applied in fluctuating water. From the statistical calculation we can see that in standing water, the systematic error of the new system is 0.01%, the incidental error under 75% accumulative frequency is ±0.03%, and the incidental error under 95% accumulative frequency is ±0.04%; In fluctuating water, the systematic error of the new system is 0.0%, the incidental error under 75% accumulative frequency is ±0.02%, and the incidental error under 95% accumulative frequency is ±0.04%. All of the results. can meet the requirement.

6 Error analysis

6.1 Artificial factors

In the original system, the data are collected and processed artificially, so the interference of artificial factors is unavoidable. However, in the new system, the data are transmitted wirelessly or through cables in the form of up level pulsing signal, and they are processed by intelligent instrument, so the interference of artificial factors is completely avoided, and so the accuracy of discharge measurement is improved.

6.2 Machinery factors

In the original system, the motion of the lead fish is controlled through coupling transformation, so the regulating range is small, and it is difficult to control the motion of the lead reposefully, and all of those greatly affect the measurement accuracy. However the new system adopts conversion technique, and the motion of the lead fish is controlled efficiently through the speed control of the electromotor, thus exact location of the lead fish come into reality, as a result the measuring accuracy is greatly improved.

7 Conclusions

The development and application of the new system improved the automation degree of discharge measuring with shorter measuring time and less labor intensity of the technicians, also raised work efficiency and the quality of the results. using this new system make the discharge measuring of water supply much more accurate, the means much more advanced, and the reliability much more higher. All of these will raise the public trust to the management of the Yellow River water resources in Shandong Province.

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Practice and Thinking of "Separate Water Supply" in the Yellow River Estuary Region

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Abstract: Dongying City located in the Yellow River mouth is the locus of the second biggest oil field in China – Shengli oilfield. Because the problem of the Yellow River mouth's zero – flow has been gradually serious since the early 1970's, large amounts of reservoirs storing and adjusting water has been built in river mouth area as far back as mid 1980's in order to resolve its zero – flow and ensure the development and resources exploitation of the city and the oilfield. Only the oilfield has 17 reservoirs whose design capacity is 376 million cubic meters. In order to manage and allocate the Yellow River water resource rationally and effectively, the Yellow River Estuary Bureau takes full advantage of these reservoirs in river mouth and has carried out the innovations about the sluices control and application methods and water supply managing mechanism, while splitting water supply in alternate time according to two different characters of the water utilization – agricultural water and non – agricultural water, which is called " the separate water supply". This method has fundamentally dissolved the water contradiction of competing for water between agriculture and industry and has built new harmonious high – effect local water utilization order, has made sufficient utilization of limited water resources and has had adjusted the Yellow River water supply structure effectively and has got good economic and social benefits.

Key words: water supply, pattern, innovation research, the Yellow River, estuary

The Yellow River water is the most preponderant resource of the Yellow River. The economy of water supply is an important component of the Yellow River economy. How do we allocate the limited water resources and bring the maximal benefit of water supply? The Estuary Bureau has been in progress of probing and practising in the Yellow River estuary area where the contradiction between water supply and demand is most outstanding from 2005. Two kinds of water for agriculture and non – agriculture are supplied at different time in the head of canal, which is called "The separate water supply". The effective operation of this pattern has fundamentally dissolved the sharpest contradiction of competing for water between agriculture and industry in river mouth area and also has changed the present inharmonious situation of the relationship for a long time between water supply departments and water use departments, exerts a favorable and far – reaching influence to boosting the healthy development of the Yellow River water supply at the same time.

1 Bringing forward of "the conception of the separate water supply"

Yellow River water supply started from the beginning 1950s. The first sluice in the lower reaches of the Yellow River is Qijiazui Sluice which was built just on the Qizui dangerous project in Lijin County which belongs to the Yellow River Estuary Bureau. There are 94 head sluices in the lower Yellow River. From 2001 to 2006, the average water supply every year was 6.86 billion m^3, of which the agricultural water was 90.5% and the non – agricultural water was less than 10%. The average water consumption in the river basin was 38.9 billion m^3 in 2002, of which agricultural water accounted for 76.9%, the municipal water accounted for 9.0%, industrial water accounted for 14.1%. Apparently, there is a very big gap in the present water supply structure and practical water used among the Yellow River lower reaches. During the recent ten years, there were many changes. Most cities become already several times lager than original in scale. The water used for city life, industry, agriculture and wastewater dilution is increasing fast. The fast development of economy and the change of society economy brought by the excessive urbanization already lead to high centralization in the city activity. Therefore, the non – agricultural water demand must increase rapidly, which is proved by the fact that water amount decreased year by year(water consumption is enlarged along water's run). Because water from upper reaches falls off and Dongying city is the located the Yellow River mouth, which presents disadvantage of using water, the problem of using water between industry and agriculture is obvious.

(1) Because diversion canals are difficult to be divided between industry and agriculture at the irrigation area, water provided in canal head is difficult to be divided. The competition for water between agriculture and non – agriculture at the irrigation season comes into being. So the contradiction with water is acute. The agriculture irrigation is concentrated on several periods such as crops reviving, injection, autumn planting and winter preservation of soil moisture mainly. Especially during the period from March to June every year, agriculture requires water most urgently. While the water supply from the Yellow River is the least of the whole year. Due to the mix of water supply, Competition for water between agriculture and non – agriculture makes the contradiction acute. Farmers are dissatisfied for the irrigation unable to be ensured. It has happened in many times during the past few years that farmers' took force to switch sluice to get water. Their extreme action went against the harmony and stabilization of society.

(2) After a dense water diversion, if agricultural water and non – agricultural water form coincidence at the lower reaches area, it is very difficult to carry out water regulation to make sure no zero – flow in the Yellow River.

(3) Since water regulation was carried out in lower reaches in 1999, no zero – flow have been kept for 8 years in the estuary area. The departments using water have already forgotten the problem of the Yellow River's cutoff and have weak concept about the scarcity of the water. Plain Reservoirs are left unused and the Yellow River water can not be utilized fully except irrigation season. According to the data about recent 10 years, water from lower reaches of the Yellow River accounts for only 47.20% of annual amount from July to October, water amount is large and water quality is good, which is suitable for non – agricultural use. But in fact water diverted accounts for only 30.74% at the same term. According to the investigation, the total storage capacity of plain Reservoirs along the Yellow River in Shandong is 2.287 billion cubic meters. But the actual utilization ratio is very low. Some even are left unused for many years, not playing the essential effect to adjust the contradiction between water supply and demand.

(4) Water price lever has never functioned in adjusting supply and demand. The low price for a long time leads to the weak saving water consciousness of departments using water along the Yellow River and the universal waste of water. Agricultural water is supplied by 1 ~1.2 Fen every cubic meters in lower reaches of the Yellow River. Due to the mix of water supply, many non – agricultural users have received the agricultural price, which leads to lower positivity of industrial users to adopting water – saving measures. Agricultural irrigation is mainly flooding. Water wasting is extremely serious. At the same time, water supply departments got less income from water due to reasonless water supply structure.

2 The major goal of implementing "the separate water supply"

The agriculture is a basic industry of stabilizing society and people's mood. They are the momentous decisions of the central authority that supports the agriculture and rural area to develop and ensures food security and farmers' interests. It is the inevitable duty for the Yellow River department to implement central authority's policy of supporting agriculture. Resolving the contradiction of competing for water between industry and agriculture, building new harmonious order of high – effect regional diversion, distributing the Yellow River water resource rationally, ensuring the need of agricultural irrigation, strengthening entire society's water – saving consciousness, especially industrial enterprise, are the starting point and the goal of putting the measure into practice which can explore a new way to adjust the structure of water supply fundamentally and improve the economic effect of water supply.

3 The conditions of implementing "The separate water supply"

(1) A number of reservoirs in the Yellow River mouth area are big. The storage capacity is large, and the adjustment ability is strong. We can take advantage of reservoirs adjustment in non – agricultural water supply, staggering water supply in the peak – hours such as irrigation in spring and sowing in autumn and so on. Non – agricultural water can be diverted into reservoirs during the period when upper water discharge is large or the agriculture has no need of water, avoid competing for water with the agriculture.

(2) Since the Yellow River water regulation has been carried out during the past few years, the Yellow River has never cut off. Therefore, agricultural water needn't be stored in reservoirs whose running cost is very high and it can enter farmlands directly. Industrial and municipal water must be diverted and desilted before entering reservoirs, which can provide condition for grasping industrial and municipal water accurately and controlling non – agricultural water amount fundamentally.

(3) The function of non – agricultural water reservoirs is unitary. The length of main conveyance canals is moderate. It is easy for the Yellow River water supply department to supervise, control and administrate water.

4 "The separate water supply"——the main methods of driving the regulation of water supply structure

4.1 Innovating the water supply thought and exploring actual running pattern of water supply objectively

Aiming at the contradiction of water supply between agriculture and industry and current situation of irrigation area in the Yellow River estuary region, we have carried out detailed investigation and study and have felt out the main canals, the branch canals, inlets, reservoir diversion networks and the practical conditions in water supply process. We also check on the area of irrigation region which has been affirmed by the head of town government. Detailed investigation and study about practical condition of using water, urban life, landscape and zoology have been carried out. It can grasp water – using data of non – agricultural departments in the past few years. So it also can prop up the separation of water between agriculture and non – agriculture forcefully.

4.2 Innovating allocation, control and management mode of the Yellow River water supply

"The separate water supply", aiming at available sluices, canels, and current diversion facilities situation, without investment and reformation, in the light of the regulation by which agricultural and non – agricultural water, puts water supply in alternative time into practice between agricultural and non – agricultural water and supplies agricultural water in mass during agriculture irrigation period. It can produce the effect of reserviors' regulation and storage, and it rearranges the structure of water supply. Under the premise of reinforcing regulation measure and ensuring river's no zero – flow in Lijin, Yellow River water was determined the characters (characters of agricultural water and non – agricultural water) from source and get controlled. The rough traditional control management to the Yellow River water resource has been changed completely.

4.3 Innovating the operating mechanism of the Yellow River water supply and management

4.3.1 Building the gear mechanism with harmonious operation

"Separate water supply" working office was founded in the Yellow River Estuary Bureau, which is responsible roundly to the management and production about water supply, licence for using water, water regulation, arranging water amount for non – agriculture and so on. The office will enhance availably the efficiency of the task to achieve "separate water supply".

4.3.2 Building the interactive benign mechanism to shares benefit

In order to implement separate water supply successfully, we have built benefit sharing mechanism. The mechanism can waken fully the positivity of departments of water supplying and irrigation area management. It will reinforce the administration to irrigation area and resolve the problem of the confusion of water use. The limitation about up water use management also can be remedied.

4.3.3 Building prompting and restriction mechanism

The Yellow River Estuary Bureau has worked out "the separate water supply" award and punishment management prescript. By the method, we will award the outstanding department or individual, while the department who do not achieve the mission will be punished. At the same time, the separate water supply will be implemented together with the new "water supply agreement" which makes clear the right and obligation of water supplier and users and indicate the punishment measure to the illegal department or individual.

4.3.4 Building perfect and effective supervision mechanism

Take measures to supervise strictly the personnel who manage the production of water supply. Emphasize the construction of inside supervision system, administration supervision system and social supervision system. Build up the supervision mechanism in which the right supervised exists together with obligation and supervision is combined organically and united in phase with being supervised.

5 The benefit analysis of "the separate water supply"

The implementation of separate water supply has solved the contradiction between the water consumption of industry and agriculture from the source when there is a shortage of water resources. The finite water resources of the Yellow River are rationally allocated. The water supply construction is readjusted. It obtains an obvious effect on both economic results and social benefits.

5.1 Economic benefits

According to the statistical analysis, from July 2005 to June 2006 seven hundred and eight million cubic meters water is diverted totally. Among them, the non – agricultural water consumption is 147 million m^3 occupied 20.8% of the total volume of diverted water during this period. However, in the past from July 2004 to June 2005 the total volume of water diverted reached to 654 million m^3. Among them, non – agricultural water consumption is 96 million m^3 occupied 14.6%. In a word, the proportion of non – agricultural water consumption is increased by 51 million in an experimental year on the basically similar water condition of the upper reaches and the total volume of diverted water in the similar period of time. In 2006, the diverted water is 892 million m^3. Among them, the non – agricultural water is 195 million m^3. Comparatively, the non – agricultural water only is 97 million m^3 in 2004 and 129 million m^3 in 2005. In the following three years from 2004, the ratio between the non – agricultural water and the total is 13.9%, 21.1% and 21.9%. By implementation of the control measure – separate water supply, the ratio between the volume of non – agricultural water and the total has increased from less than to more than twenty percent. The proportion of non – agricultural water consumption has been improved. The economic results of water supply are obviously enhanced.

5.2 Social benefits

It is mainly shown on the following several points.

(1) The separate water supply of agriculture and non – agriculture has solved the contradiction between the agricultural water consumption and the non – agricultural water consumption. On this point, it guarantees the agricultural water consumption on the condition of the shortage of the Yellow

River water.

(2) The separate water supply has rightly settled all kinds of relationship among the departments of water supply, irrigated area and water use. It also has promoted the harmonious development among those departments. By strictly specifying the character of water, the whereabouts of water is controlled from the source. The Yellow River department, the management departments of the irrigated area, the terminal agricultural and industrial user can obtain the exact volume of water consumption. By this way, people can be clear of the volume of water and pay the charges of water willingly. It founds a harmonious and highly effective water supply pattern.

(3) The total volume of diverted water tends to decrease and the water volume of estuary has increased comparatively, which would exert a favorable influence on the ecology of the Yellow River Delta.

6 Conclusions and recommendation

(1) The change of water supply structure is the foundation of improving the economic benefits water supply. The Yellow River' water supply is the project with the largest economical potentiality. The water volume of lower reaches allocated by the nation (including Hebei province and Tianjin city) is 14,54 billion m^3. According to the rate of socio – economic development on the water supply region at the present, especially the rapid economic development and the over urbanization, there will be a substantial growth in the ratio between non – agricultural water consumption and the water volume of lower reaches allocated by the nation. On the basis of the relative statistical data, the ratio between non – agricultural water consumption and the total water supply is 25% ~ 30%. If the non – agricultural water consumption of the lower reaches of the Yellow River totally achieves the ratio of 10% ~ 15%, the revenue of the Yellow River water supply will be more than doubled.

(2) The separate water supply is the basic measure to divide the regional non – agricultural water consumption objectively and exactly at present and adjust the structure of water supply effectively. The control management of the Yellow River water supply is not only simply the management of sluice on the lower reaches. The more important work is walking along the cnnels. The definition and measurement of water quality (agricultural and non – agricultural) objectively and exactly is the basis of the structure regulation of water supply.

(3) The implementation of the separate water supply has two important meanings. On one hand, people can get the consumption volume of non – agricultural water in the period of time at the approved region objectively and exactly. On the other hand, it establishes the foundation of the water right transition of the Yellow River for next step (the issue of agricultural water transited for industry) to manage and allocat water resource of the Yellow River through market.

(4) The socio – economic steady rapid development and over – urbanization have a larger and larger demand for the non – agricultural water consumption (from now on, the growth of the water consumption of the Yellow River is mainly from the non – agricultural). However, the potential water supply of the Yellow River does not increase. Facing with so grave imbalance between supply and demand, people have to carry out the management policy of demand lying in supply in a down – to – earth manner. At the same time, people have to speed up the process of water right transition of the Yellow River. Besides, people should have a further consideration about raising price of non – agricultural water consumption to make it play a role of the price leverage to adjust supply and demand and control the over – high – speed of non – agricultural water consumption, and prevent the non – agricultural water consumption by occupying the agricultural water consumption. Therefore, it can lay a sound condition for constructing harmonious water supply of the river basin.

Water – sediment Regulation Influence on the Yellow River Water Supply in Henan Province and Countermeasures

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Abstract: Five year water – sediment regulation experiments from 2002 to 2006 made the lower reaches of the Yellow River course scour, which is vital significant for maintaining the healthy life of Yellow River. Water level with the same discharge reduced, caused by river bed undercut, have influence on the water diversion along the Yellow River. This article used two – dimensional silt mathematical model in the lower reaches of the Yellow River, calculated and analysized the silt distortion situation after the water – sediment regulation of Henan section, obtained the evolution tendency of the river course after water – sediment regulation as well as the adverse effect on water diversion caused by river bed evolution, and proposed corresponding solutions.

Key words: the Yellow River, lower reach, water – sediment regulation, water diversion from the Yellow River, river bed evolution

Yellow River is the important water source of industry and agriculture in Henan Province. Yellow River water supply has become vitals of the economy development of the local area along the Yellow River in Henan Province. However, water diversion is accompanied with sediment. The multi – annual mean amount of silt which enters the lower reach of the Yellow River is 1.6×10^9 t, approximately 4×10^8 t silts up in the river course of lower reach of yellow river, which causes the downstream river course raise about 10 cm every year. With the development of water diversion from the Yellow River, matched projects in large – scale irrigation area and water – saving reconstruction projects start in Henan Province. The silt becomes an important restriction factor to the water diversion from the Yellow River. Five year water – sediment regulation have been implemented since 2002, came into operation in 2005, and obtained remarkable effect. About 4×10^8 t silt deposited in the downriver course was discharged into the sea. The suspended river is alleviated, the flowing ability of the downstream river channel has also been enhanced obviously. water – sediment regulation also brings the new question for the water diversion from the Yellow River for both banks while making the theory confirmation and practice exploration.

1 The situation of the Yellow River water supply before water – sediment regulation

The weather of the area along the Yellow River in Henan Province is the continental monsoon climate, the precipitation is less unevenly distribution in the year. The seasonal drought often occurs, the water resources is extremely deficient. Ground water is the main water resouce of majority areas and cities along Yellow River. For a long time, we lacked unification management and reasonable use for groundwater and exploited ground water excessively without control and plan, which caused water level of ground water decline, ground water resources dry up, land sedimentation, soil desertification and the underground water source pollution. About more than 3/4 of the shallow ground water can not meet drink water standards, and more than 1/5 of ground water does not conform the irrigation water consumption standards. The Yellow River as the biggest guest water resources in Henan Province, has gradually become the substitution water source of ground water resources.

With the development of local economy and the advancement of the cities, the scarce condition of water resources is further intensified, the water resources of the Yellow River has become the important water source of the industries and urban. Therefore, the water diversion volume has been increasing year by year. The water demand of the Yellow River for various areas has been also rising year by year. Because the Yellow River sediment transportation is huge before water – sediment regulation, the bed of the downriver raises year by year, therefore so long as the Yellow River is not zero flow, the water supply can be realized. According to data in " Optimization regulation and Saving water Technology Applied research of Well Ditch in the irrigation district from the Yellow River in Henan province combined with water Resources", the multi – annual average water diversion volume is 3×10^9 m^3 in the irrigation district from the Yellow River in Henan Province.

2 The change of scouring and silting for the Yellow River river course in Henan section after water – sediment regulation

The Yellow River carried on the experiments of water – sediment regulation for 5 years from 2002 to 2006, started operation in 2005. With the increasing ability of flow holding sediment of Yellow River, sharp scouring happened in the river course of Yellow River in Henan. During the period of water – sediment regulation experiments, the discharge of more than 2,000 m^3/s at Lijin hydrology station of Yellow River lasted for 98 days, which causes the Yellow River downriver river course scour obviously.

This article computes and analyses the change of scouring and silting of downstream Yellow River course in Henan section after water – sediment regulation, which uses two – dimensional silt mathematical model in the Yellow River downriver river course. Basic equations are as follows:

Continuity equation:

$$\frac{\partial Z_s}{\partial t}+\frac{\partial (HU)}{\partial x}+\frac{\partial (HV)}{\partial y}=0 \tag{1}$$

Momentum equation:

$$\begin{aligned}\frac{\partial U}{\partial t}+U\frac{\partial U}{\partial x}+V\frac{\partial U}{\partial y}&=-g\frac{\partial Z_s}{\partial x}-\frac{\tau_x}{\rho}+\left(\frac{\partial^2 U}{\partial x^2}+\frac{\partial^2 U}{\partial y^2}\right)\\ \frac{\partial V}{\partial t}+U\frac{\partial V}{\partial x}+V\frac{\partial V}{\partial y}&=-g\frac{\partial Z_s}{\partial x}-\frac{\tau_y}{\rho}+\left(\frac{\partial^2 V}{\partial x^2}+\frac{\partial^2 V}{\partial y^2}\right)\end{aligned} \tag{2}$$

in the formula: x,y is Descartes vertical and horizontal component; U,V is the perpendicular mean velocity in x, in y direction component; Z_s,Z_b is water level and the river bed elevation; t is time; H is perpendicular water depth of datum plane relatived, $H=Z_s-Z_b$; ρ is water density; τ_x,τ_y is the shear stress in x, in y direction component.

Silt continuity equation:

$$\begin{aligned}&\frac{\partial}{\partial t}(A_iS_i)+\frac{\partial (A_iV_iS_i)}{\partial x}+\sum_{j=1}^{m}(K_{sij}\alpha_{*ij}f_{sij}b_{ij}S_{ij}\overline{\omega}_{ij})-\\ &\sum_{j=1}^{m}(K_{sij}\alpha_{*ij}b_{ij}S_{ij}\omega_{ij})-S_{Li}q_{Li}=0\end{aligned} \tag{3}$$

River bed distortion equation:

$$\frac{\partial Z_{bij}}{\partial t}-\frac{K_{sij}\alpha_{*ij}}{\gamma_0}w_{ij}(f_{sij}-s_{*ij})=0 \tag{4}$$

In the form of (3) ~ (4), i is the cross section number; j is the sub – cross section number, the lowest cross section number of the river bed elevation j is 1, the highest is m; A for water flow area; t for time; x for coordinates along distance; Z for water level; ω is the sedimentation velocity of silt muddy water; S for silt content in water flow; S_* for water flow transportation sediment ability; γ_0 for the dry density of silts in the river bed; b_{ij} for the width of sub – sectional; Z_{bij} for the average river bed elevation of sub – cross section; α_* for distributed coefficient of silt content.

The water flow transportation sediment computation uses the formula on the Yellow River is :

$$S_*=2.5\left[\frac{(0.002,2+S_v)V^3}{k\dfrac{\gamma_s-\gamma_m}{\gamma_m}gh\omega_s}\ln\left(\frac{h}{6D_{50}}\right)\right]^{0.62} \tag{5}$$

in the formula: ω_{sk} for the group sinking velocity of the k group of particle in muddy water; D_{50} for the median diameter of bed sand (mm).

The roughness coefficient formula is:

$$n = \frac{c_n \delta_*}{\sqrt{g} h^{5/6}} \left\{ 0.49 \left(\frac{\delta_*}{h} \right)^{0.77} + \frac{3\pi}{8} \left(1 - \frac{\delta_*}{h} \right) \left[\sin \left(\frac{\delta_*}{h} \right)^{0.2} \right]^5 \right\}^{-1} \tag{6}$$

in the formula: δ_* for the thickness of frictional resistance, the relation formula of δ_*, bed sand medium diameter D_{50} and Fr is:

$$\delta_* = D_{50} \left\{ 1 + 10^{[8.1 - 1.3 Fr^{0.5} (1 - Fr^3)]} \right\} \tag{7}$$

This model selects the river bed synthesis stability index from Zhang Hongwu as the adjustment criterion of river computation, namely:

$$\frac{\left(\frac{\gamma_s - \gamma}{\gamma} D_{50} H \right)^{1/3}}{i B^{2/3}} = \varepsilon_* \tag{8}$$

in the formula: B for river width; i for the vertical gradient of river bed. For the adjustment of river width (including from sectional width) is confirmed by formula (8).

After the model is established, takes the data of water and sand during the period of water - sediment regulation which from 2002 to 2006 year for the Yellow River as the computation basis, uses the flood season from 2002 to 2006 for computation. The computed result is in the Fig. 1 ~ Fig. 4.

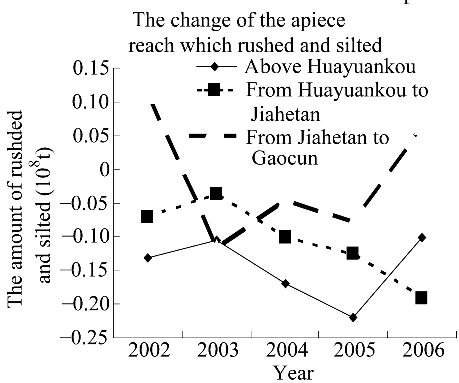

Fig. 1 Statistics of river scouring and silting change for various sections

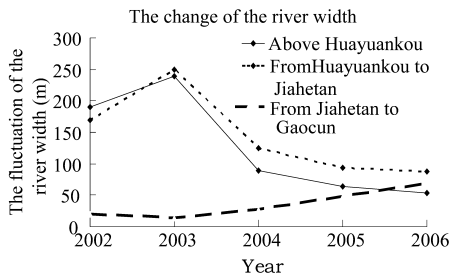

Fig. 2 The statistics of river width change

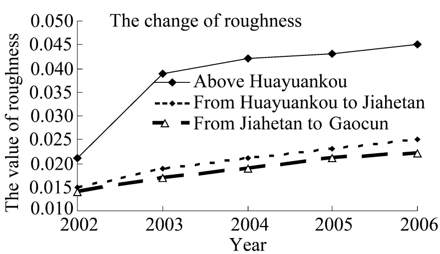

Fig. 3 Statistics of river roughness coefficient change for various river section

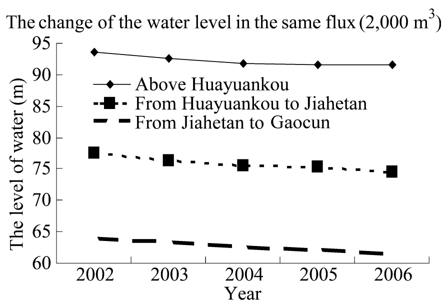

Fig. 4 Statistics of water level change with same discharge

The results form 5 years water and sediment regulation computation data are: During five water – sediment regulation from 2002 to 2006, the sediment washed away is 1.418×10^8 t in the section from Xiaolangdi to Gaocun. 0.725×10^8 t silt washed away in the section from Xiaolangdi to Huayuankou, the intensity is 4.87×10^5 t/km; 0.524×10^8 t in the section from Huayuankou to Jiahetan, the intensity is 3.70×10^5 t/km; and 0.167×10^8 t in the section from Jiahetan to Gaocun with the intensity of 2.78×10^5 t/km.

During five years water – sediment regulation period , the Yellow River course in Henan section is basically scoured for the entire line (Fig. 1). Among of them: the section above the Huayuankou scours deeply; the section from huayuankou to jiahetan scoured with the water and sediment regulation, the main channel brushed deeper and deeper; The section from Jiahetan to Gaocun undergoes the process of silting, scouring, then silting. But it can be seen from the data, at present, the section scoured severely is above Jiahetan. With implementation of water – sediment regulation, the section scoured downstream year by year.

We can see from the results of the model computation and analysis, the section above huayuankou, the main channel scoured deeply, but some of the cross section became wide, the stretch scope is 300 ~500 m , the average river bottom elevation of this section drops about 0.48 m; river morphology change in the section from Huayuankou to Jiahetan changed, the main channel became wide because of flood plain collapses, the average width is 150 m, the average bottom elevation of river drops 0.14 m; river morphology in the section from Jiahetan to Gaocun is stable, the project control is better, the main channel scoured deeply, the average depth is 0.5 m (Fig. 2).

With the river scoured, the river bed gradually coarsens, causes resistance bigger. With water – sediment regulation, the roughness coefficient of various sections increase (Fig. 3). With the river bed of upper section coarsening, the resistance will increase, which will causes river downstream coarsen. Simultaneously the majority river cross section will become narrow and deep; the sections which has less project will collapse more seriously. If the samll discharge lasted, the scour will be weakened. but when the discharge into downstream changed, the scour and silt quantity every water volume will increase, even if the upper reach which had been scoured would be scoured again.

This article choose the water level with the discharge of 2,000 m^3/s as comparison, it can be seen that water level with the same discharge descend, which shows that the main channel are in state of scour. From Fig. 4, although water level with same discharge declined, but water level above Huayuankou drop gently, the section from Huayuankou to Jiahetan drop sharply, while the section from Jiahetan to Gaocun drop fastly, it illustrates that main channel scour is evolved to downstream year by year.

Five years Water – sediment regulation, by regulation of reservoir, silt disturbition and water diversion control, make unbalance relationship of different source area, different magnitude, different silt grain composition into the harmonious water sand composition, and cause the downstream river course silt reduction, even scouring along the distance. After scoured, high flood plain and deep channel formed, the flow ability of the river channel has increased, it is good to stable river morphology, reduce the river course flood water level and reduce river channel silt. Simultaneously, large – scale water – sediment regulation causes the river bed drop in the section of Henan Province, the main channel became deep and narrow from wide and shallow.

3 The influence on water supply in Henan Province of water – sediment regulation

Water – sediment regulation of the Yellow River causes downstream river course scour sharply, it has positive significance for flood prevention of Yellow River, but compared with the same discharge of last years, water level of Yellow River dropped, ditch of the irrigation district silt up seriously, gate for water drawing is not in good state. After water – sediment regulation, water level with different discharge drops year by year, from 2002 until now, average drop is bigger than 1 m. This situation causes water drawing ability of gate greatly reduced when small discharge occurs, even can not draw water.

The problems of river bed decline and water level decrease caused by water – sediment regulation make it difficult for water drawing from Yellow River of Henan. Especially in the spring irrigation season of February, March, April of every year, Not only the water volume of the Yellow River is smaller, moreover the water level is lower, appears the phenomenon which the Yellow River has water but can not be draw out.

The size of the water drawing ability is not only decided by the Yellow River discharge. Also decided by water level of the floodgate, the floodgate ledger wall and the ditch bottom relative altitude back of floodgate. In recent years, because of the affects of water – sediment regulation, the river bed continuously scour, water level with the same discharge declined sharply, water drawing ability reduce seriously. The small discharge water drawing causes ditch back of floodgate silt up, raised the ditch bottom elevation, causes water drawing difficult, and formed vicious circle.

water – sediment regulation of the Yellow River start into operation in 2005, the river bed will continuously scour in next several year, the water drawing ability will reduce further. With the development of industry and agriculture in Henan Province, it will lead water use of local area along the Yellow River increase year by year. but the water coming from upstream reduce year by year. Therefore, the situation of the water supply from the Yellow River in Henan Province is severe, should be paid high attention, take the corresponding countermeasures, so as to reduce the adverse influence on water supply of Henan caused by water – sediment regulation.

4 The countermeasures taken by Henan water supply from Yellow River

Aim at the adverse influence on water supply of Henan caused by water – sediment regulation, this paper take measures for 3 aspects: the ditch reconstruction, management of water drawing and supply, adjustment and control during water – sediment regulation on own initiative, main contents are as follows:

4.1 Measures for ditch reconstruction

(1) Construct pumping station for drawing water In front of the gate

During spring irrigation period, water used is bigger than usual , but the water coming from downstream is very small, the contradictory between water supply and demand from the Yellow River is prominent. Construction of pumping station may fundamentally solve the phenomenon of "Yellow River with water can not direct" caused by river bed undercut and water level with same discharge drop, to guarantee need of water use for people life and spring irrigation.

(2) Main ditch cross section reconstruction, reduce main channel silt caused by small discharge

The real operation discharge at the beginning of main ditch can not achieve the design discharge and velocity in most of the irrigation district. This is the important reason of main ditch silt up. Therefore, part of ditch can be changed into compound section, adjustment of roughness coefficient, cross section, bottom slope, water depth and so on, so as to satisfy the main channel can achieve the design dischrge which does not scour and silt of flow in the situation of different water drawing, causes the main channel silt up a little or silt up not at all.

(3) Building or repairing sluice is to reduce the sand into the main ditch from the Yellow River silt

sluice should be set for blocking the sand in front of the floodgate to reduce sand into the main ditch. The function of this sluice is to obstruct the coarse sand, which may deposite at the beginning of ditch, raise the ditch bottom level, reduce water drawing head, influence water drawing ability seriously. Therefore, when Yellow River discharge is bigger, sluice should be used to block sand for reducing ditch silt up.

4.2 Management measures of Yellow River water supply

(1) Regulation scientificaly

Drawing water should be regulated scientificly, big discharge water supply should be used , which can make the main ditch maintain high water level and big velocity, in order to reduce the main channel silt up. In November and December every year, the Yellow River silt content is smaller, at this time , big discharge, high water level water drawing should be carried on to scour the ditch and reduce the sediment in the ditch. Simultaneously the irrigation area should carry on removing the sediment in the ditch to prepare for the spring irrigation.

(2) Enlarge investment for silt clearing

The investment for silt clearing is huge because of the ditch silt seriously caused by water – sediment regulation. It is difficult only depending on the irrigation own district, therefore, it is suggested that the communist central committee, local province department and related department make favorable policy, increase fund for silting clear, exert the project operation.

(3) Regulative measure during water – sediment regulation

Water – sediment regulation is the important means to maintain river course function from now on. During the implementation, industry and agriculture water used should be thought about to guarantee floodplain security. During the water – sediment regulation, it can define the index of water drawing at different river section, adujsting water order, establishing river course main ditch evolution monitor feedback mechanism and so on, thinking about the reservoir, discharge regulation to guarantee water use from the Yellow River.

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Discussion on Problems against Water Diversion in Xiaokaihe Irrigation District under Water and Sediment Regulation of the Yellow River

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Abstract: Water and sediment regulation is a symbol project which the Yellow River Administration carries out the transition for method of harnessing the Yellow River. The purpose is to form rational water and sand process during the real – time dispatching of the reservoir. It benefits to control the sediment in the lower reach of the Yellow River, even to scour alongside the whole river, and achieve the purpose that the river bed can't be raised. In short, utilize Xiaolangdi Reservoir to store water, discharge with high flow, artificially make flood peak, scour the river channels in the lower reach, and increase the safety of flood prevention and control. Since 2002, Yellow River Administration has made water and sediment regulation in successive years, trial has been changed into running. The water and sediment regulation will make the river deep by scouring. The water lever of the Yellow River will decrease under the situation of same flow. The water diversion capacity of the irrigating district will also decrease. In additional, being influenced by the limit of water from the upper reach as well as the existing problems of headwork of the Yellow River diversion and Yellow River diversion irrigation district, the contradictions of demand and supply for Yellow River diversion irrigation district will continuously sharpon. Based on the conditions of water and sediment regulation of the Yellow River, incorporated with the actual situation of Xiaokaihe irrigation district, we have preliminarily investigated and analyzed the existing problems for irrigation of the Yellow River diversion and also provided related countermeasures and suggestions in this paper.

Key words: water and sediment regulation, irrigation of the Yellow River diversion, existing problems, discussion

1 Water ntilization for Agricultural Irrigation

Since 1999, Yellow River Conservancy Commission (YRCC) has implemented unified management and dispatch for water resource of the Yellow River, under the condition of successive low water lever, the river channel has not been dried up for eight years. This is an unique large river which water drying – up problem has been solved in the world. The successive water flow has effectively support the development of economy and society in Shandong, especially the two cities in the lower reach i. e. Binzhou and Dongying. It basically ensures the water demand of living and production alongside the Yellow River. Currently, there are 68 counties (cities or districts) in 11 cities are utilizing the water of the Yellow River. The capacity of the Yellow River diversion and irrigation districts of the Yellow River diversion almost account for 40% of the total water utilization and irrigation districts in Shandong Province. The water supply of the Yellow River diversion plays a decisive role in the strategic position of national economy in Shandong. Based on the statistic of the whole province for the capacity of the Yellow River diversion of the last five years, the cities alongside the Yellow River account for up to 80%. The average agricultural water utilization alongside the Yellow River is 4.434 billion m^3, where Heze 0.7 billion m^3, Ji'nin 0.103 m^3, Liaocheng 0.43 billion m^3, Dezhou 1.004 billion m^3, Ji'nan 0.348 billion m^3, Zibo 0.077 billion m^3, Binzhou 0.968 m^3, and Dongying 0.804 m^3.

2 Background of Xiaokaihe Irrigation district

The Xiaokaihe irrigation district of the Yellow River diversion is a large – scale irrigation district of the Yellow River diversion approved by the State Planning Commission, Ministry of Water Resources and Provincial Planning Commission. It involves 420 thousand of population in six counties (districts) i. e. Bincheng, Development Zone, Huimin, Yangxin, Zhanhua, and Wudi. The designed irrigation district is 73. 33 thousand ha. The designed flow of water diversion is 60 m^3/s. The annual designed water diversion is 0. 393 billion m^3. The irrigation district started to build in 1993. It completed to implement water diversion in 1998. The whole length of main canal is 91. 5 km. Where the sand diversion canal is 51. 3 km, water diversion canal is 36. 04 km, sedimentation basin is 4. 16 km, main buildings 147 units, full – section lining of sand diversion canal is 20. 7 km, and half – section lining is 30. 6 km. The total investment is 0. 23 billion RMB Yuan.

Xiaokaihe sluice of the Yellow River diversion is constructed in 1994. Elevation of sluice bottom is 14 m (Dagu elevation, hereinafter the same). The dimension of hole is 3 m × 3 m box culvert. The designed water flow is based on the temporal water lever of 16. 2 m in the Yellow River, and the corresponding water flow is 218 m^3/s. The designed water diversion is 60 m^3/s. For the average elevation of river bottom of the Yellow River in front of the Xiaokaihe sluice, it was 15. 5m before water and sediment regulation and it is almost 14. 0 m in current.

3 The Existing Major Issues and Causes for Irrigation of the Yellow River Water Diversion

Among all kinds of utilization for the Yellow River water, the water consumption of agricultural irrigation is the highest, which accounts for 80% of the total water consumption. As a series of policy to benefit farmers are established such as state "Three Reductions or Exemptions, Four Allowances" and building the socialist new rural area, the enthusiasm which the peasants grow grain is increasingly rising. The cultivated area in the irrigation district is enlarging. The demand of the Yellow River water resource is also continuously increasing. However, being influenced by the limit of water from the upper reach as well as the existing problems of headwork of the Yellow River diversion and Yellow River diversion irrigation district, the contradictions of water demand and supply are sharpening. The following items show the existing major issues:

3.1 The river scours deeply, the water lever falls, the capacity of water diversion is decreasing

Since 2002, the water and sediment regulation has implemented for five years successively with remarkable achievement. It is surveyed that the accumulative scoured depth of the riverway and channel was 0. 87 m in 2005. Especially, in the lower reach of Binzhou, under condition of same flow, compared with 2002, the maximum scoured depth of the riverway was 1. 06 m in 2005 with average value 0. 92 m. Because the most gates of the Yellow River diversion were constructed in 1970s ~ 1990s, they are constructed based on the continuous sediment of the riverway. The bottom of gate is higher. The water and sediment regulation make the stream channel become deep. The water lever falls under the situation of same flow. The fall of water diversion is decreasing. All of these will cause the capacity of the Yellow River diversion to decrease. In addition, because the main stream deviates, the length of front canal of gate for water diversion is increasing. That the Xiaokaihe main stream for gate of the Yellow River diversion deviates and keeps away from the entrance of gate will cause the difficulty to water diversion. Compared with 2001, the diversion canal before gate increased 50 m, the distance also increased, and the resistance of water content increased also in 2006. Statistics shows that under the current situation of 200 m^3/s of flow in the large river, the water diversion capacity of gate in the lower reach is decreasing one – third compared with that of 2001. As the water and sediment regulation is carrying out, the conditions of partial gates are more deteriorated. Especially, since the water and sediment regulation of 2004, compared with the 200 m^3/s flow of 2002, the water diversion capacity of more than ten gates have decreased almost 50% such as Dayuzhang, Xiaokaihe, and Bojili in Binzhou as well as Mawan, Gongjia, and Caodian in Dongying reach, which seriously influenced the irrigation of these gates. The following shows the comparisons for the water diversion flow of Xiaokaihe gates for the Yellow River water diversion.

Table 1 Comparison for yearly actual water diversion lever of Xiaokaihe gates of the Yellow River water diversion

Year	Designed Water Lever before Gate (m)	Actual Water Lever before Gate under the 400 m^3/s Flow of the Yellow River (m)	Actual Water Lever before Gate under the 300 m^3/s Flow of the Yellow River (m)	Actual Water Lever before Gate under the 200 m^3/s Flow of the Yellow River (m)
1999	16.2	17.7	17.05	16.63
2000	16.2	17.8	17.11	16.7
2001	16.2	17.52	17.18	16.87
2002	16.2	17.35	16.98	16.62
2003	16.2	17.2	16.74	16.39
2004	16.2	16.71	16.33	16.03
2005	16.2	16.35	16.04	15.65

Table 2 Comparison for the water diversion days, flow and water volume of gates of the Yellow River water diversion

Year	Water diversion days	Yearly average flow (m^3/s)	Water volume (ten thousand m^3)
1999	59	25.63	13,066.5000
2000	127	18.15	19,918.5000
2001	105	14.51	13,162.8000
2002	202	15.96	27,852.9000
2003	141	9.43	11,490.0000
2004	102	8.30	7,313.0000
2005	119	12.40	12,749.2000

Table 3 Comparison for the water diversion before and after water and sediment regulation of Xiaokaihe

Date	Luokou flow (m^3/s)	Lijin flow (m^3/s)	Water diversion flow (m^3/s)	Water lever before Gate	Remarks
2003.5.27	77	46.2	13.3		Target of water diversion
2003.6.1	108	35.8	22.0		Target of water diversion
2006.2.20	194	107	1.8	15.3	Maximum water volume
2006.3.1	320	130	6.7	15.6	Maximum water volume

Based on the data of above table, for the two times of water diversion in 2003, the targets given by the Yellow River Administration were 13.3 and 22.0. However, the actual water diversion capacity will be more than these values.

3.2 The sediment before the Yellow River diversion sluice and depositing in river channels will bring about the difficulty to water diversion

Statistic by the Yellow River Administration shows, among the 58 units of intake doors for gates of the Yellow River diversion in the Yellow River Shandong Bureau, there are 12 units has been broken off from the river and 15 units has been deposited. There are 25 units of diversion canal has been deposited. This is because that the water lever falls under the situation of same flow of the Yellow River. Furthermore, due to the scoured depth of the stream channel, regime of river will be more stable. Once the water diversion is stopping, the reach before gate will be deposited. It will cause difficult water diversion of most gates under the situation of lower flow. In addition, due to the less water from the upper reach, for each gate of the Yellow River water diversion, the actual water diversion flow is far less than the designed water diversion flow. It causes the continuous sediment of the channel and deterioration of the water diversion condition. That the water lever of channel head is lower will cause the velocity of flow for water diversion to decrease and the capacity of carrying sand to decrease. It will cause the serious sediment of channel. On the contrary, the sediment of channel will influence the water diversion capacity of channel head. Furthermore, in order to increase the water lever of the lower reach of the Yellow River, the flow of the Yellow River is increasing, and corresponding sand content is increasing, the sand diversion content in irrigation district is increasing, and the canal system is deposited, the water diversion capacity of irrigation district is also decreasing.

Due to the trajectory jet of 32# jetty head of the Yellow River before the gate of the Yellow River diversion of Xiaokaihe, the main stream of the Yellow River keeps away from the gate of the Yellow River diversion. The backwash is formed before the gate. The sediment before the gate is serious when water diversion is stopping. Since 2004 ~ 2005, the sediment before the gate and the gravels of former dam base before gate has been cleared for six times. Due to instability of water in the Yellow River, the water lever is unstable. The sediment has been cleared before gate for four times. Basically, sediment was cleared prior to each water diversion. The accumulative cleared sediment was up to 23 thousand m^3. The cost was up to 69 thousand RMB Yuan. Meanwhile, because it is impossible to clear the sediment before gate thoroughly, partial sediments enter into the channel. The sand diversion capacity is also increasing. The workload of sand treatment in the irrigation district is increasing. It causes the sediment of canal head for stream channel of sand transferring is serious. The maximum height of sediment is almost 1.70 m. It seriously influences the water diversion capacity of irrigation district.

3.3 The stream channel becomes narrow, the velocity of flow increases

Due to successive scour of water and sediment regulation, the main stream channel of the Yellow River becomes narrow. The radial velocity of flow of stream (i.e. the velocity of flow towards the lower reach) increases. Correspondingly, the divergent velocity of flow in connected with water diversion for the gate of the Yellow River diversion is decreasing. The kinetic energy toward the lower reach is increasing. According to the conservation of energy, the corresponding potential energy is decreasing. Namely, the water lever before the gate is falling and the velocity of flow is decreasing.

3.4 The water consumption in irrigation district is increasing and the water from the upper reach can't meet the demand

In recent years, in order to generate electricity and store sufficient water in Xiaolangdi for water and sediment regulation, during irrigation in spring, the discharge flow of Xiaolangdi Reservoir maintains below 700 m^3/s. Without consideration of water diversion in the upper reach, maintenance of ecological water demands for typical estuaries in the Yellow River, and the loss flow of waterway, the available flow for spring irrigation in Shandong is almost 400 m^3/s. However, the spring irrigation in the lower reach is more concentrate and the maximum water diversion is almost 1,000 m^3/s. The water from the upper reach can't meet the demand at all. The Wudi County locates the lower reach of Xiaokaihe irrigation district, the designed irrigation district is 536.8 thousand mu which accounts for 50% of the designed irrigation area of Xiaokaihe irrigation district. In general, with consideration of water loss of 55.5 kg stream channel, the water diversion flow for the number of gate of the Yellow River diversion is at least 15 or above, the water can outflow. During the spring irrigation, the number of gate of the Yellow River diversion shall be at least 45 or above and the water utilization in the upper reach must be properly controlled so that the water in the lower reach is sufficient.

3.5 The water – saving consciousness in the irrigation districts is poor and the utilization coefficient of water is lower

In current, the irrigation of the Yellow River in Shandong is mainly flooding irrigation and serial irrigation. For the irrigation of water diversion, the absolute equalitarianism for water utilization is adopted. On the one hand, on the management system i.e. no more payment for more water consumption and no less payment for less water consumption, the water cost is disconnect with the water consumption, the water fee is basically allocated according to the population or areas of land averagely; on the other hand, there are not associated projects. As the reconstruction of associated water – saving is carrying out in the state large – scale irrigation district for stream channel, the anti – penetration ratio of the stream channel is gradually increasing. However, most of the lower reach of branch channel is earth cannel for water transferring and they are aging and disrepair with serious spillage, leakage, and penetration. The utilization coefficient of water is mostly lower than 0.5. The utilization ratio of water is lower. Within the Xiaokaihe irrigation district, except that the water is measured to transfer to the villages and towns in Wudi County, the cost fee in the other counties and districts is basically allocated averagely no matter whether water utilization or not and the amount of water consumption.

4 Countermeasures and suggestions

(1) Control the scour depth of water and sediment regulation properly. In current, the water and sediment regulation of the Yellow River Administration is changed trial phase into normal running. The water and sediment regulation is performed every year. The stream channel continues to scour deeply. If scour is allowed to continue, it will not benefit to the water diversion of irrigation district, some gates of the Yellow River diversion cannot meet the demand of water utilization of irrigation district, or the water can hardly diverted and even be scrapped. If so, it will not benefit to the social stability, the safety of state grain, and the construction of socialist new rural areas. Even the water for human and livestock drinking can't be ensured. The consequences would be too ghastly to contemplate. We suggest that the water and sediment regulation will no longer be made under meeting the basic requirement of flood prevention and control of the Yellow River, or the water and sediment regulation will be made once an every other year. We will find a break – even point between the flood prevention and control of the Yellow River and water diversion of irrigation district. With consideration of both factors, we will achieve the win – win goal.

(2) Scientific dispatch of the Xiaolangdi Reservoir should be made and the water storage should be increased. During irrigation seasons, the discharge volume should be increased to raise the water lever of the lower reach and meet the maximum requirement of water diversion in the lower reach. During non – irrigation seasons, under the premise of ensuring the demand of generating electricity and flow of Lijin reach into the sea, minimize the discharge volume to increase water storage.

(3) Scientific dispatch of the Yellow River should be made. Concentrate its effort to ensure large – scale irrigation districts with higher flow and shorter time. Overcome the phenomenon of

lower flow. Reduce the regulating number of water diversion target. Increase to have the initiative in their hands for scientific dispatch of irrigation districts.

(4) Increase the flow of Lijin control reach into the sea, keeping more than 180 m^3/s. It will not only maintain the healthy life of the Yellow River but also raise the water lever in the lower reach of the Yellow River. It will benefit to the water diversion of the irrigation districts.

(5) Strengthen water saving. Through the measures such as construction of projects, strengthening management, and working out specific measuring unit, link the water fee and water consumption, and activate the water – saving enthusiasm of water users. This is the only way to achieve the purpose to save water and optimize the allocation of water resource.

(6) Utilizing pumping station to divert the water into the channel, the cost of irrigation will increase. Because the water lever falls after water and sediment regulation for the gate of the Yellow River diversion of Wangzhuang irrigation district in Dongying, the water of the Yellow River can hardly be diverted. In February of 2006, a pumping station with 30 m^3/s was established before the gate of the Yellow River diversion to divert the water into the channel. The investment is more than 11 million RMB Yuan. The electricity fee in the spring of each year is more than 1 million RMB Yuan. It is only subject to the water cost. The water cost is increased by 2 cents of per cubic meter water. The cost of management division and water users are increase.

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New Exploring Way of Yellow River Water Resources Allocation in Shandong Province

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Abstract: Aiming at the main problems along the river in Shandong area, such as shortage of water resource, restriction on socioeconomic development, prominent contradiction between agricultural and industrial water use, severe water resource waste and no – flow of the Yellow River, the implementation of separate water supply in agricultural and non – agricultural water use is an effective measure under the present situation of water diversion infrastructure, water use law, pilot situation and implementation effect, which will promote the development of society and economy in a harmonious way and the establishment of water – saving society, and will develop a certain function in preventing no – flow phenomenon of the Yellow River. Separate water supply of agricultural and non – agricultural use is a systematic project, which need an all – dimensional and multi – level cooperation and coordination.

Key words: Shandong Yellow River, water resources allocation, separate water supply

1 Preface

Water is the un – substitutable resource for human living and development, and is the important foundation for sustainable and harmonious development of society and economy. Shortage of water resource and the manner of water distribution have become the crucial factors that influencing sustainable development of economy in Shandong's areas along the Yellow River, harmonious development of society and whether the Yellow River can re – appear its thriving life. The deep research of the manner of water resources allocation and supply is becoming urgent.

Shandong Province is located at the eastern coast of China, which passes through the Yellow River basin, Huaihe River basin and Haihe River Basin. Shandong Province has already developed to become an important province in economy and population through Reform and Opening – up since 1978, whose economy is vigorous. In the meantime, Shandong is also up against contradiction between water resources supply and demand. Data from 1956 ~ 1999 display that the annual average precipitation is 676.5 mm, annual average water resource is 30.582 billion m^3 in Shandong Province. The whole water resource in this province is 1.09 percent of national water resources. Per capita water resources of Shandong Province is 344 m^3, which is 14.7 percent of national per capita water resources, 4 percent of global per capita water resources and last fourth in China, belonging to absolute water – scare regions which per capita water resources is less 500 m^3.

2 Development and present condition of Yellow River water supply

Yellow River water supply in Shandong Province begin from the early part of 1950's. With the development of national economy and society, the contradiction of water resources supply and demand was increasingly outstanding. Yellow River water supply also suffers from incipience to maturity, from disorder to order, from scattered management to centralized management.

2.1 Enhancement of water supply ability

The first Yellow River Supply Sluice its name is the Qijiazui Sluice was built in Lijin in 1950, its designed discharge was 1 m^3/s. Through the construction for more than 50 years, there were 180 Water Intakes along the Yellow River in Shandong Province their designed discharge was 2,551.4 m^3/s, among which the number of more large – scale infuse area was sixty – three which include fifty – three sluice and nine pumping station. 753 Reservoir in the plain area had been Built in Shandong Province along the Yellow River their designed storage capacity was 1.476 billion m^3.

2.2 Scale extension of water supply

The area and scale of Yellow River water supply expanded distinctly through the development of half century. There were 57 irrigation regions whose dimension was 6.65 million acres and initial ability was to supply agricultural water and drinking water in Lijin and Zhamhua, which included 11 cities today. The water supply object had also developed from singular agricultural water to agricultural water, industrial water and water for residential use. From 1990 to 2005, the average water diversion in Shandong Province from the Yellow River was 6.359 billion m^3 annually, which was 25 percent of total practical water demand in Shandong Province.

2.3 Change of water distribution manner

Management of Yellow River water supply passed from disorder to order, from single production control to combination of production control and resources´management, which followed legalization and scientific orbit of process gradually. After 1990s, along with reduce of input water and radical increase of water demand, Yellow River dry – up appeared frequently which impacted the economic development along the Yellow River and residential life, destructed ecological environment excessively. For suppressing aggravation of the Yellow River ecological environment, the Nation authorized the Yellow River Conservancy Commission (YRCC) to administer the Yellow River water resources in 1999. In 2002, the Water Supply Bureau of Yellow River Shandong Bureau was established which brought Yellow River water supply into combination of water resources regulation and water supply management

3 Problem of Yellow River water supply in Shandong province

Although Yellow River water supply in Shandong Province has obtained outstanding result, conflict between supply and demand of Yellow River water resources turned worse further. There were still many problems in water supply, water use and water resources allocation.

3.1 Prominent contradiction of agricultural and non – agricultural water use in agricultural irrigating season

Agricultural water in Shandong province was utilized in the period of returning green stage, grain filling regulation, autumn grows and keep moisture in winter etc. Agricultural water demand was most urgent in annually Marly March – June, but in same period Yellow River downstream's input water was also withered in a year. Under the condition that non – agricultural and agricultural canal – system was in common; non – agricultural and agricultural water supply was not separated, conflict of non – agricultural and agricultural water was urgent.

3.2 Incomplete function of flood storage of plain reservoirs

According to the data of the past 10 years, input water of the Yellow River in Shandong Province from July to October was 47.20 percent of that in whole year, but at the same time water supply was 17.07 percent of that in whole year only. Total effective water storage of plain reservoir in Shandong province was 1.378 billion m^3 whose water comes from the Yellow River, but average availability coefficient was only 0.5 or so, whose flood storage function had not been exploited.

3.3 Incomplete function of the water price leverage

Agricultural water price was low over long period of time, which cause to management department of irrigation region lack investment to construct canal – system and agricultural water – saving measures. Yellow River irrigation region currently utilized flood irrigation and string irrigation. The ratio of lining in main canal is only 7.5%. The availability coefficient of water in Yellow River irrigation region was 0.4 or so, which is half of that in the developed countries. On the other hand, due to mixed supply of agricultural and non – agricultural in same canal – system, many non – agricultural user attained agricultural water price, which weakened the advantage of water price leverage.

3.4 Threat to no – flow of the Yellow River

The data shows that annual average input water of the Yellow River in Shandong province was 20.88 billion m^3 from 1990 to 2004. Average input water of the Yellow River in Shandong province is 6.67 billion m^3 from March to June, which was only 31.9 percent of annual average runoff discharge. At the same time, water demand was 3.592 billion m^3 in Shandong province, which was 56.3 percent of annual average water diversion. The phenomena of Yellow River dry – up in Shandong Province appeared frequently from 1972, the frequency is 72 percent of total dry – up frequency, which demonstrated that Yellow River dry – up was result from combination between lack of seasonal input water and inordiante water diversion. There was a positive relation between Yellow River dry – up and inordiante water diversion.

3.5 Restriction to establishment of water rights transaction

The water right conversion is that water right bodies deal with its right under the condition of water resources lacks tightly. There are three infallible factors: ①water resources lacks tightly; ②water resources use is private attribute; ③water behavior boundary of dissimilar bodies is clear. Agricultural water use index from the Yellow River in Shandong Province is 85 percent of total water use index, which results in that new using water project has no water use index from the Yellow River. For the sake of harmonious configuration of water resources and continuous development of economic society in Shandong Province, new means of water rights transaction must be established. But water behavior of varying water user can not be demarcated clearly, which hamper the application of water right conversion.

4 Separate water supply – the realistic way of Yellow River water resources allocation

4.1 The basic implication of separate water supply

Water resources can be demarcated agricultural water and non – agricultural water. The agricultural water mainly points to water which is utilized to plant, farming and village drinking water. Non – agricultural water means water which is outside of agricultural water. Separate supply means using same canal system, agricultural water was supplied in agriculture irrigating season, flood storage function of plain reservoir do duty for non – agricultural water in other time. Separate water supply is a new means which balance agricultural water and non – agricultural water by supply in different time without increasing canal system and water resources.

4.2 The possibility of separate water supply

There are two way to achieve separate water supply. The first is to rebuild the canal system of non – agricultural water, which will possess 17,000 acres and need costly investment. Obviously this path is not economic and workable. Another is to adopt separate supply in different time according to regulation of agricultural water and non – agricultural water by existing canal system and plain reservoirs. Owing to factors mentioned follow, the author points to separate water supply is a realistic path of Yellow River water supply in Shandong Province.

4.2.1 Water storage capacity of existing plain reservoirs can satisfy non – agricultural water in agriculture irrigating season

According to water use analysis in the past years, average annual non – agricultural water was 0.6 billion m^3 along the Yellow River in Shandong Province. Water storage capacity of plain reservoirs in Shandong Province was 1.378 billion m^3 whose water comes from the Yellow River. Theoretically storage of all reservoirs was full once can satisfy non – agricultural water demand in one whole year. If separate water supply is carried out, non – agricultural water supply is limited in agriculture irrigating peak (6 months), which can not impact industrial and residents use water.

4.2.2 Water storage of plain reservoirs in secluded and high elevation region can be resolved

The plain reservoirs which are far from the Yellow River supply sluice include Dingdong Reservoir, Dingzhuang Reservoir and Xingfu Reservoir and so on. For the sake of reducing water loss along the canal and enhancing efficiency, reservoirs mentioned above can reserve water with agricultural irrigation.

4.2.3 The pressure of Yellow River dry – up can be alleviated

There are 22 dry – up of the Yellow River from 1972 to 1999, in which 16 dry – up appeared from March to June. During March to June average month water diversion was 1.08 billion m^3 which was near month input water. Separate water supply limiting non – agricultural water from March to June can obliterate 0.2 to 0.3 billion m^3 of water diversion peak, which can alleviate pressure of Yellow River dry – up effectively.

4.2.4 Separate water supply is beneficial to agricultural production and harmonious relationship between city and countryside

Carrying out separate water supply is to finalize the "San Nong" Policy in management of Yellow River water resources and Yellow River water supply, which can provide cogent support to development of countryside. Separate water supply can not only undertake demand of agricultural production in agriculture irrigating peak, but also establish concordant order of water supply, which can promote industrial and agricultural development and create advantageous social milieu for national economy and society development along the Yellow River.

4.2.5 Separate water supply can accelerate establishment of water – saving society and water rights transaction market

Price leverage is one important part of Economic measures, which can exert significant effect to optimize water resources. Now the problem of water right is that industrial and agricultural water user can not be demarcated clearly. Separate water supply can facilitate the establishment of water saving consciousness, wastewater treatment, water – saving society and favorable ecological environment. At the same time, water bodies are made a clear distinction can expedite the establishment of water rights transaction market.

5 The implementation of separate water supply

Two ways were carried on to check real condition of water circumstance along the Yellow River. Water Supply Bureau assembles pertinent sections to carry out an investigation in cities and irrigation areas along the Yellow River. On the other hand, the Statistic Department was entrusted to investigate water demand and water use law of 9 cities, more than 20 corporations and 24 reservoirs, which gleaned accurate data for separate water supply.

Water Supply Bureau popularized the lack of water resources, contradiction between water resources supply and demand, value of water resources integrating administration, immense impact of no flow depletion of the Yellow River and maintain Yellow River health life to all levels government and irrigation area management sectors along the Yellow River in Shandong Province, which was attained comprehension, improvement and support.

Dongying City was chosen as experimental site of separate water supply, whose dependence on the Yellow River water is greatly and the contradiction is extrusive between agricultural water and industrial water. During experiment, plan was made to resolve problems and difficulty such as disagreement, inactivity and re – allocation of benefits etc. which obtained success. Based on experience of experimental site, separate water supply was applied completely in Shangdong Province. During separate water supply, Water Supply Bureau changed traditional measure which only managed sluice and water supply, did not manage ditch and purpose. Water Supply Bureau cooperated with Water Administrative Department closely to check water supply contract, water volume and water rate. Non – agricultural water intake and irrigation area were censored and supervised, which avoid industry use agricultural water and achieve extensive management from water intake to irrigation area and user and undertaken the application of separate water supply.

6 Effects obtained from separate water supply

The experiment of separate water supply was made in Dongying City in 2005, which obtained anticipative result and social approval. People's Daily, Dazhong Daily, CCTV and many kinds of network medium did a full affirmation. Office in State Department also introduced separate water supply exclusively in the Everyday Information.

Separate water supply resolved conflict between non – agricultural and agricultural water demand in agriculture irrigating peak, which accelerates the application of the San Nong Policy and establishment of concordant relationship between industry and agriculture, city and countryside and water – saving society. Separate water supply undertakes agricultural water demand in agriculture irrigating peak, which realized irrigation of 3,300 km^2 in high elevation region and average growth of provisions is 225,000 kg/km^2.

Separate water supply use advantageous occasion for non – agricultural water supply in flood season and winter to increase non – agricultural water supply. Non – agricultural water supply in 2006 increased more 0. 21 billion m^3 than that in 2005, which increased 0. 198 billion m^3 than average in Tenth Five – Year Plan period. Separate water supply undertakes No Flow Depletion of the Yellow River and essential flux into the Yellow River Delta, which maintain ecological environment of the Yellow River estuary effectively.

7 Conclusions

Separating water supply can be adopted theoretically and practically, which is a new means of water supply and new idea of water resources allocations. Application of separate water supply can resolve existing problems of Yellow River water supply, and accelerate development of harmonious society and maintain Yellow River health life.

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Study on the Causes and Countermeasures of Decrease of the Yellow River Water Irrigation Area

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Abstract: In recent years, due to the shortage of water resources and the increasing demand for water with the rapid socio – economic development and population growth, the contradiction between supply and demand for water resources is increasing in the Yellow River. Because of the serious sediment deposition in the channel, the disrepaired supporting projects, the low utilization rate of water channels, the imperfect irrigation management and the decline of the supply guaranteed rate, the irrigated area is decreasing. Aimed at the contradiction between supply and demand of water resources, it need to combined the irrigation actual needs, to restore the expansion of the irrigation district through engineering and non – engineering measures, to establish a complete management and control means, to allocate the water resources rationally, and to transfer water scientifically, so that the limited water resources yield the greatest economic returns.
Key words: irrigation by water from the Yellow River, area decrease, causes analysis, countermeasure study, engineering construction, tenders and bids, tendering agent

1 Decrease of irrigation area and its impact

The downstream irrigation area of the Yellow River is the largest gravity flow irrigation area in China. It is the important base for grain, cotton and oil crops. It has been playing a big role in keeping stable and high output of grain, cotton and oil crops. Before 1990s the supply water from the Yellow River was increasing, but decreasing later.

Most of the existing irrigation areas in China were established in three periods, at the end of 1950s, at the beginning of 1960s and 1970s. Because of the low construction standard, the imperfect supporting engineer, the lack of the maintenance and management, the utilization rate of water resources is very low after running them for decades of years.

There are 2 irrigation areas Yangqiao and Sanliuzhai in Zhongmu County, Henan Province. The Yangqiao Irrigation Area was established in 1970 and operated in 1975, covering over 10 towns. Sanliuzhai Irrigation Area was established in 1965, covering 5 towns. Since the operation of the Zhongmu irrigation area from the last century, the Zhongmu irrigation area has been enlarged and 539,100 mu has been accomplished, including Yangqiao Irrigation area 274,100 mu and Sanliuzhai Irrigation area 265,000 mu. In the over 20 years before 1992, the average water volume drawn were 246 million cubic meters and the real irrigated area were above 450,000 mu. The irrigated area which in 2005 was only 160,000 mu decreased to 80,000 mu in 2006. The Yangqiao irrigation Area stopped to operation in 2006. On one hand, the water resources are seriously short, on the other hand, the water resources cannot be used fully. The diversion volume of Yangqiao and Sanliuzhai in 2005 approved by the Yellow River Concemvemcy Committee are respectively 80 million cubic meters and 25 million m^3 but the water drawn of Sanliuzhai in 2005 and 2006 are 19,936,800 m^3 and 24,491,700 cubic meters respectively, and the water drawn of Yangqiao in 2005 and 2006 are 17,354,400 m^3 and zero m^3 respectively.

The first sluice of the Zhaokou Channel undertakes the distribution of the irrigation water in the Zhaokou Irrigation areas such as Kaifeng, Weishi, Tongxu, etc. Also it has ever conveyed water to the surrounding areas such as Zhoukou, Yanling etc. But because of some reasons such as the lack of the integrated planning, without the clarifying management system, and with misuse and retaining of the charges for water, the irrigated areas are reducing year after year. The drawn water volume in 2000 is only about 50% of that in 1995. In 2006 the drawn water volume is zero.

Because the seasonal peak period of water can not meet the demand for irrigation, and sometimes not even take water, some problems such that the peasants appeal to the higher authority for help, delay or refuse to pay the water charges often occur, and the enthusiasm of drawing water from the Yellow River is not high. Because the irrigation water for farmers has no guarantee, the farmers have lost their confidence in using the Yellow River water, and readjust the structure of farming, which has lead to the irrigation well increase and the water drawn from the Yellow River reduce year after year. At last the irrigation efficiency of the projects can not be played fully, and the cost – effectiveness is difficult to embody. For example, in 2003 the Yangqiao irrigation area can not supply water normally, which has result in 1.6 million mu of rice can not be planted, and the paddy had to switched to growing the corns. The economic loss of the rice seedlings nurtured hit more than 60 million yuan. After July, 2005, because the flow discharge in the Yellow River is small, the volume of the diversion water in the sluice can not meet the demand for water in the irrigation area, which has lead to the 4,200 mu of rice planted to grow corn, soybeans, and other dry crops.

Impacted by the lateral seepage, most lands are alkali soil in the irrigation areas along the Yellow River. In the early stage of the irrigation, the effects of the warping irrigation to improve the soil, discharge the alkali and control the silt are very obvious, and the surrounding groundwater resources have been changed greatly. If the Yellow River Irrigation Area stopped irrigating or reduced the irrigation area substantially, the consequences will be very serious. Firstly, most of the land along the Yellow River region will occur on sub – salinity, land back to the salt, Soda, and the change of the soil qualitative nature; secondly, because the neighboring groundwater can not be added effectively, the long – term pumping of underground water for irrigation will make the water table has dropped dramatically. The groundwater resources is diminishing, and which eventually leads to the water resources can not meet the demand for agricultural irrigation; Thirdly, it is very difficult to maintain the structures in the irrigation area and the farmland works such as branch channel, tertiary canal, feeder canal, distributing ditch etc. Fourthly, increase the economic burden in the irrigated area. According to the estimation, comparing the cost of per mu of the warping irrigation and well irrigation, the warping irrigation can save about 30 yuan, and it can save both time and energy. Based on the calculation of the 200,000 mu irrigation area existing in the Yangqiao irrigation area, the farmers have to pay more than 6 million yuan only for irrigation annually; Fifthly, break the local ecological environment and ecological structure.

2 Main reasons that result in decreasing of the irrigated area

2.1 Low probability of irrigation

At present, because of the low perfection rate of facilities in most irrigation areas and large loss of the irrigation water due to the leakage and evaporation, the probability of irrigation water is low. Above half medium and low yield lands results from drought. Especially in the continuous dry years, most lands are changed into glebes because of the low probability of irrigation water. The sub – saline and sub – alkaline land come out again in some region due to the irrigation ceasing for a long time, which leads to the reduction of output, even no output.

2.2 Serious damage of the structures in irrigation area for the disrepair of the project for many years

For long – term irrigation ceasing without management leads to damage to channels, the water drawn in the irrigation area decreased greatly. Because of the shortage of funds, the controlling ability of the irrigation area decreased. The large and medium projects invested by the state are well built, but the sub – channels built under funds financed by peasants themselves have bad quality because of shortage of funds and they are damaged, leading to the waste of water and the decrease of the irrigated area year after year. The effective utilization coefficient is only 0.45, so the project's benefit cannot be exerted.

2.3 Backward irrigation method, high irrigation quota and serious waste of water resources

In the past, welfare water is supplied in wide villages. Although water resources are short, they are wasted very seriously. Flooding irrigation exists in most villages. Peasants have not sense to save water, leading to serious waste of water. Seepage and leakage protection is not available and water resources are wasted.

2.4 Imperfect management system and operation system

Management system and mechanism in irrigation area can not meet the requirement of the market economy. The water management agency only pays attention to the construction but no attention to management. Because of shortage of funds in most irrigation areas, low irrigation management level and backward technology, no good operation system can be established. Irrigation water charge is collected by government and it cannot maintain normal operation of irrigation area. Peasants have low sense to take part in management and the water disputes are frequent. Management unit lacks funds and labor. Salary of personnel cannot be guaranteed and staff team is not stable. These impact the implementation of management and exertion of project's benefits. Peasants have no sense of responsibility to operation and maintenance of the projects, benefits of which gets increasingly decreased.

2.5 Sediment deposition in channel and difficult diversion from sluice

Because the mainstream of the Yellow River is moving frequently and the channel before sluice is too long, for example, that of Zhongmu Yangqiao reaches 4 km, the serious deposition leads to the diversion water difficult. The drawn water decreased year after year with the low guarantee rate and low utilization rate. Irrigated area is getting decreased year after year. There is no water drawn through this sluice in 2006.

2.6 Untimely the Yellow River water supply for farming season

Agricultural irrigation water is seasonal, as the Yellow River flow is too small, the allocation of water resources is irrational, and the supplied water is not timely, particularly in the peak period of the agricultural irrigation, the masses are forced to switch to well irrigation to make up for the insufficiency. After many years they have lost the confidence in the Yellow River irrigation, and the well irrigation area switched from the Yellow River irrigation area is increasing year after year.

2.7 The water charge standard is low, and the water charge is not available on time and in full

Now, the water price at lower reaches of the Yellow Rive is far off its value seriously, which makes against the improvement of water save concept of all circles and results in the waste of water resources then the normal maintenance and good operation of project can't be guaranteed.

At present, 0.04 yuan per m^3 is charged in irrigation area, 0.01 yuan per m^3 is given to the Yellow River Management Department and town government shall undertake 0.015 yuan. Irrigation area only charges 0.015 yuan that cannot be charged fully in time. Because of imperfect measuring facility and nonstandard charging channels, each town charges by mu. Water price is lower than water cost and water price of user in irrigation area is higher than current water price. The proportion of price in real charging standard and cost price is relatively lower. Shortage of funds full exertion of benefit of irrigation area is impacted, which restricts normal operation and development of irrigation area. Price of the Yellow River water is lower and water supply project cannot get normal maintenance, which gave an edge to contradiction between supply and demands, impacting development of irrigation undertaking.

2.8 Serious impact on irrigation effect from sediment deposition

There is large content of sediment in the Yellow River water, but it lacks effective measures for diversion of sediment. Most sediments deposit in channels. It needs high cost to treat the sediment and the sediment occupies large quantities of lands. There is still not any applicable treatment, which make irrigation difficult in the high concentration of sediment period.

3 Countermeasures to enlarge irrigated area

3.1 Large benefit from enlarging irrigated area

In accordance with the investigation, the annual gross river water consumption of rice is 1,500 m^3, garlic 800 m^3 and wheat 500 m^3. Water fees by 0.04 yuan/m^3 are respectively 60 yuan, 32 yuan and 20 yuan. By the electromechanical well irrigation, water fee per 100 m^3 is 8 ~ 10 yuan, and by the diesel oil well irrigation 12 ~ 15 yuan. Water fees per mu are respectively 120 yuan, 64 yuan and 40 yuan. Time, effort, and machine are saved in river irrigation without hardening of soil. If measures are applied to restore the irrigation for 10,000 mu, more than 400,000 yuan (RMB) will be saved annually, and about 7,000 mu can be supplied with water from the Yellow River.

3.2 Scientific management to promote water supply rate

Flow shall be enhanced at agricultural season and change the passiveness situation that industrial, living and agricultural water consumption cannot be coordinated. It shall be guaranteed that the water is supplied completely in time to make peasants active in water utilization and recover and enlarge irrigated area. Because water is goods, peasants who buy it shall be guaranteed. Only when satisfied, they will give water charges fully and be confident in water leading. Thus irrigated area can be enlarged.

3.3 To renovate the channel to improve the water drawing rate

Aimed at the deposition, the dredging equipment is purchased to remove sediment in the channels to guarantee the normal water supply in irrigation district.

3.4 To charge the water fee in advance

Since the irrigation from the Yellow River water, the welfare charge is applied to the agricultural water consumption and it is charged annually. Water supply department applies measurement as to town that doesn't do to villages. The villages cannot measure water and peasants have not clear water charges. It is charged by mu and it is difficult to be charged. It is suggested that each town apply measurement to each village and village charge by mu and times. In order to decrease trouble and work loads of personnel, the water can be charged in advance. And it is checked after a season. This can raise the peasants' awareness to water goods and peasants' enthusiasm to draw the Yellow River water.

3.5 To enhance management and to establish the water supply company and water user associations (WUA)

In a long term, planned economy goes in China and collective ownership goes in agricultural production and establishment and management of water facilities. Although the special management is combined with the peasants' management in irrigation area, it is embodied in government and collective. To combine special management with peasants' management, connect water project and management unit to water users and establish the Water Supply Company and WUA. Give the rights of projects under sub – channel to WUA and achieve self – financing of project funds, independent economy and development of water industry in accordance with economic laws.

3.6 To establish a reasonable water charge

The current water charge is far lower than the cost, which cannot evoke the people's awareness of water saving. It is an effective measure to establish the reasonable water price and improve charging system to stop waste and promote water saving. Work out market system in accordance with the peasants' economic bearing capacity and water quality. Analyze the supply and demands of water and soil resources in irrigation areas to ascertain water prices in different periods.

3.7 To reform the end channel project in irrigation area

After long – term operation, the end channels have low guarantee probability of irrigation and the disputes are frequently caused, which have direct impacts on exertion of the project's benefit. As high yield and stable yield lands, irrigation areas play a critical role in national grain safety. Include the end channels into governmental management, set reform funds, reinforce investment for reform, recover and enlarge the irrigated area and promote the production capacity.

3.8 To enhance publicity, communicate actively and form a good water supply and consumption environment

The Yellow River lacks of water resources and the contradiction between water supply and demands is obvious. Active communication between both parties of supply and demands shall be carried out. Adopt different forms and take advantage of opportunities to propaganda the importance and necessity of coordination of contradiction between supply and demands and to make the governments at different levels and the users aware that every drop of water is not easy to get. Through great propaganda and analysis of advantage and disadvantage, gain understanding, support and cooperation of governments and users to create a good social environment of water supply for the Yellow River water irrigation.

4 Conclusions

Because of shortage of water resources in China, the crisis of water supply is becoming a more practical problem than ever before. How to maintain the sustainable development of the Yellow River water resources has been the first to promote the sustainable development of society and economy of the Yellow River basin.

The Yellow River water is useful to the growth of crop and can improve soil with obvious production increase. Increment benefit of RMB 10 million will be achieved from each 0.1 billion m^3 of the Yellow River water led. Groundwater can be supplied to improve underground funnel and the ability of waters to be self – purified can be enhanced, which improves local surface water and release water pollution. Fully exert irrigation benefit, reform water saving in irrigation area, promote the utilization rate of conveying water of channel, popularize water saving irrigation technology and establish a good management and operation system in irrigation area.

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Study on Structure of Water Resources in the Downstream of the Nenjiang River

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Abstract: Flood water utilization is one of effectual measures to relieve the water shortage. This measure not only can lessen the flood disaster, but can increase the supply of the water resources. At the point of the river ecosystem balance, river water utilization and flood protection, the theory of the River Water Structure (RWS) can be introduced. According to this theory the river water can be divided into four parts, namely environment water portion (EWP), safety water portion (SWP), risk water portion (RWP) and disaster water portion (DWP). The limit boundaries between the different water portions are the vital factors in the RWS, which can be determined by different methods.

Based on the hydrologic data from 1953 to 2002, the RWS of the Jiangqiao and Dalai hydrologic station can be researched. According to the calculation results, the annual four water portions variation tendency, the four water portions proportion of the long – time average annual value and the characteristic years as well as the appearing frequency of the RWP and the DWP can be analyzed. The results indicate that the theory of the RWS can provide better thinking for the flood prevention as well as utilization of river water more effective.

Key words: Nenjiang River, Flood water utilization, River water resources, structural analysis

In the case of water shortage, how to actively utilize the river water resources has become one of important measures to relieve this crisis. At present, more researches about water resources distribution are with a view to the macroscopic field. For the river water resources, few people take the structure of itself into account to improve its utilization ratio. The meaning of the River Water Structure (RWS) is that the river water is divided into different parts according to the demands for exploitation and the environmental protection (Xu Shiguo, Li Wenyi, 2005). The proper division can make people utilize the river water more reasonable and effectual.

1 The theory of the division of the river water structure

1.1 The essential thinking of the river water structure

The target of the river water division is the total water of the stream channel. At the point of flood prevention and utilization, according to the characteristic of the river flood as well as the different functions and actions possessed by the river water, the river water can be divided into four parts (Xu Shiguo, Li Wenyi, 2005), namely environment water portion (EWP), safety water portion (SWP), risk water portion (RWP) and disaster water portion (DWP). The division of the different water can be figured by the Fig. 1.

The three curves a, b, c indicate the different frequency (5%, 10% and 25%) runoff process of the Dalai hydrologic station (one of hydrologic stations in the Nenjiang River), respectively. The Q_{L1}, Q_{L2} and Q_{L3} are the boundary water levels between different water portions. Q_R is the actual flow of the river; Q_{L1} is the boundary between the EWP and the SWP; Q_{L2} is the boundary between the SWP and the RWP; Q_{L3} is the boundary between the RWP and the DWP.

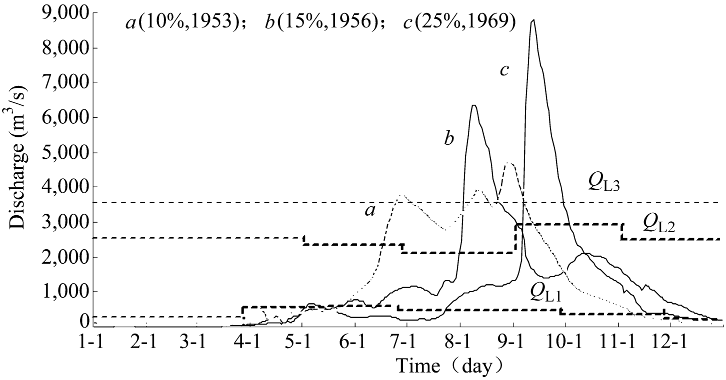

Fig. 1 The diagrammatic sketch of river water structure (RWS) in the northeast China

1.2 The calculation methods of each kind of water portion

The discharge is a very important indicator of the river, which is highly accordant with the river runoff (the relationship between them shown by formula (1)). Because most of the river hydrological data are recorded by discharge, which can be regarded as the most important parameter when researching the RWS.

$$V = \int_{t1}^{t2} Q(t)\,dt \tag{1}$$

where, V is the river runoff from time t_1 to t_2; $Q(t)$ is the instantaneous discharge of the river; t_1, t_2 is computation start time and end time.

The following formula can be used to compute the four kinds of water portion:

$$V_E = \begin{cases} \int_{t1}^{t2} Q_R(t)\,dt & Q_R \leqslant Q_{L1} \\ \int_{t1}^{t2} Q_{L1}\,dt & Q_R > Q_{L1} \end{cases} \tag{2}$$

$$V_S = \begin{cases} \int_{t1}^{t2} [Q_R(t) - Q_{L1}]\,dt & Q_{L1} < Q_R \leqslant Q_{L2} \\ \int_{t1}^{t2} [Q_{L2} - Q_{L1}]\,dt & Q_R > Q_{L2} \end{cases} \tag{3}$$

$$V_R = \begin{cases} \int_{t1}^{t2} [Q_R(t) - Q_{L2}]\,dt & Q_{L2} < Q_R \leqslant Q_{L3} \\ \int_{t1}^{t2} [Q_{L3} - Q_{L2}]\,dt & Q_R > Q_{L3} \end{cases} \tag{4}$$

$$V_D = \int_{t1}^{t2} (Q_R(t) - Q_{L3})\,dt \qquad Q_R > Q_{L3} \tag{5}$$

$$V = V_E + V_S + V_R + V_D \tag{6}$$

where, V_E, V_S, V_R, V_D is expressing the quantity value of the EWP, the SWP, the RWP and the DWP respectively; V is the total the quantity value of the river runoff; $Q_R(t)$ is the actual discharge of the river.

Because it is difficult to continuously record the river discharge and it is unnecessary to know the continuously instantaneous discharge at most actual cases, thus in most cases only to know the average river runoff $\overline{Q}$ can satisfy the applied demand. The formula (7) is often used in practical application.

$$V = \sum_{i=1}^{n} \overline{Q}_{ti} \Delta t_i \tag{7}$$

where, n is the computation time – interval amounts; $\overline{Q}_{ti}$ is the average discharge at i; Δt_i is the time span.

2 The determination of the boundaries between the different water portions

2.1 The determination of the low limit boundary Q_{L1}

In the nature, the river has formed the relatively steady ecosystem, which possesses a certain extent anti – interference feature (Xu zhixia, Chen minjian, Dong zengchuan, 2004). There is the certain order of nature with the high and low water period, and the river ecosystem can adapt certain extent even the extreme low water.

In the northern area of China, the river water changes within a wide range (see Table 1). The river ecosystem is very weak in low water period, especially in fish reproduction period (from the April to June). During this period, the fish is very hypersensitive to the water temperature, discharge velocity and depth of water (Sun tao, Yang zhifeng, 2005). But at the same time, the agricultural water usage is also in a high grade, then the conflict with the water supply and demand is very obvious. In high water period, commonly the river runoff is in a high grade, the minimum water usage by the river ecosystem can be satisfied automatically.

Table 1 The average monthly flow of lower reach of the Nenjiang River

	Months	1	2	3	4	5	6	7	8	9	10	11	12
Jiangqiao	discharge(m^3/s)	43	29	39	303	678	840	1,328	1,978	1,586	894	293	103
	proportion(%)	0.5	0.4	0.5	3.7	8.4	10.4	16.4	24.4	19.5	11.0	3.6	1.3
Dalai	discharge(m^3/s)	52	35	48	252	628	741	1,057	1,901	1,830	1248	497	154
	proportion(%)	0.6	0.4	0.6	3.0	7.4	8.8	12.5	22.5	21.7	14.8	5.9	1.8

The river biology mainly includes algae, phytoplankton, zooplankton, large – sized water plant aquatic, benthic animal and fish. Each kind of biology has its low water limit, but it is very difficult to determine all of them at the present time. Then the indicator organism method can be selected to determine the low limit of the river ecosystem. According to this method, if the living space of the indicator organism is satisfied, the minimum living space of other organism's can be satisfied at the same time. Contrasting with other biocoenosis, the fish lies in a high grade among the river ecosystem, which possesses the important action to the existence and stabilization of other organism (Liu J. K., 1999). In addition, the fish is sensitive to the low water level, and then the fish can be selected to as the indicator organism.

The fitting discharge velocity is the necessity for the fish reproduction. According to the research results, the most optimally discharge velocity range for the fish is from 0.3 m/s to 0.4 m/s in the northeast of China and the fitting discharge velocity range for the Cyprinus carpio is from 0.12 m/s to 0.70 m/s (Wang Wu, 2000).

According to the runoff characteristic of the river water as well as the river ecosystem demand at different period, the 12 months of one year can be divided into several periods of time, namely last Dec to March, Apr to June, July to Sep and Oct to Nov. The period from Last Dec to March is the live through the winter; the fish need little for the river water. The period Apr to June is the period of the fish reproduction; the fish need biggish river water. The period July to Sep is the high water period, the low water limit of the fish need commonly can be automatically satisfied. In the period of Oct to Nov, the fish is about to enter into the period of the live through the winter, the fish need less river water. At the point of guarantee the low water limit for the river ecosystem as well as the living characteristic of the fish, the minimum river discharge velocity of the different periods of time can be determined (see Table 2). And then the low water limit boundary can be determined based on the cross – section geometrical boundary condition of the different river reach.

Table 2 The minimum river discharge velocity of the different periods of time

period of time	Last Dec ~ March	April ~ June	July ~ Sep	Oct ~ Nov
Minimum discharge velocity (m/s)	0.12	0.3	0.20	0.15

2.2 The determination of the upper limit boundary Q_{L2}

According to the states of river runoff at different periods, the 12 months of one year can be divided into four periods, namely little water period (LWP, from the Nov to April), pre – flood season period (PSP, from the May to June), interior flood season period (ISP, from the July to Aug) and terminal flood season period (TSP, from the Sep to Oct).

The upper limit of the SWP can be determined by the bankfull discharge (the flowing capacity of the main river channel). According to the research results with the main course topographic data as well as the rating curve of the hydrologic station of the Nenjiang River, the main course scour – and – fill keeps balance (Sun J. C., 2002). For the river of little sediment concentration, the flowing capacity of the main river channel generally changes little after the flood season. Thus when calculating the SWP, the bankfull discharge can be considered no variation. In the little water period (LWP), the river runoff commonly can't reach to the bankfull stage. In order to ensure safety of the stream channel, the upper limit boundary of the SWP can be determined following to the regulation: the Q_{L2} is gradually reduced during the period of the pre – flood season period (PSP) and gradually enhanced during the period of the terminal flood season period (TSP).

When the water level reaches to the bankfull stage, a little rise of the water level will greatly increase the river runoff. There is a clear curvature change on the rating curve near the bankfull stage. According to the rating curve, the bankfull stage and the bankfull discharge can be derived. Certainly, the rating curve is different between the rising and falling stage, but the different usually is little, which can be plotted according to the long – time average annual value of the water level and the discharge (Fig. 2).

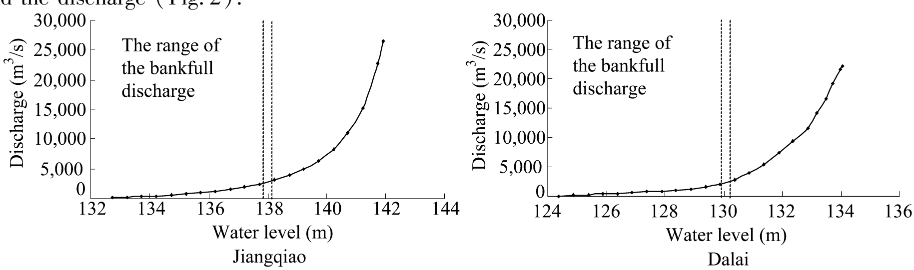

Fig. 2 The rating curves of the Nenjiang River (Jiangqiao and Dalai hydrologic stations)

2.3 The determination of the limit boundary Q_{L3}

The RWP and the DWP appear accompanying with the process of river water rising to the flood plain. As far as the river, the water of which rising to the flood plain is not always appearing every year. While to determine the limit boundary between the RWP and the DWP, the specificity water level can be referred to of the flood prevention control section. The warning water level (the river water reaches to the flood land or rises to menace the embankment) is an important index mark in the parameters of flood prevention. The meaning of the warning water level implies, at this water level, that the river probably has brought on certain dangers to the embankment and some proper measures need be taken to avoid the flood disaster. Thus the warning water level can be taken as the limit boundary between the RWP and the DWP. According to the rating curves of the hydrological station, the runoff corresponding to the warning water level can be determined (see Table 3).

Table 3 The warning water level as well as corresponding discharge of the Nenjiang River

Hydrologic station	Warning level (m)	Corresponding discharge(m^3/s)
Jiangqiao	138.50	3,300
Dalai	130.10	3,800

3 The Water Structure (RWS) theory applied in the downstream of the Nenjiang River

Jiangqiao and Dalai are the two important hydrologic stations in the downstream of the Nenjiang River. Utilization the hydrologic data from 1953 to 2002, according to the aforementioned methods the limit boundaries of variant cases between different water portions can be determined (see Table 4).

3.1 The four water portions analysis of the Jiangqiao and Dalai hydrological stations

According to the results of the limit boundaries (see Table 4), the annual four water portions volume of the Jiangqiao and Dalai hydrological stations can be figured out (see Fig. 3). The Fig. 3 can be concluded: ①The same water portion of the two hydrologic stations presents similar variation tendency. ②The annual EWP of the two hydrologic stations fluctuates less, relative stabilization, but usually the quantity of which Jiangqiao less than Dalai. ③The annual SWP quantities of the two hydrologic stations are nearly equal, and the fluctuation of which is similar to the annual runoff. ④ The amplitude variation of the RWP and the DWP are larger, and it doesn't appear the two water portions in many low flow years. ⑤In 1998, the RWP of Jiangqiao and Dalai are 4.9 billion m^3 and 7.9 billion m^3 respectively, but the DWP of them are 31.9 billion m^3 and 19.9 billion m^3 respectively.

Table 4 The limit boundaries between the different water portions of Jiangqiao and Dalai hydrologic stations

Water portion	Limit boundaries	Period of time (month)		Limited value	
				Jiangqiao	Dalai
The EWP The SWP	Q_{L1}	Last12 ~ 3	The limited discharge (m^3/s)	196	217
		4 ~ 6	The limited discharge (m^3/s)	473	512
		7 ~ 9	The limited discharge (m^3/s)	308	347
		10 ~ 11	The limited discharge (m^3/s)	227	265
The SWP	Q_{L2}	The LWP (last11 ~ 4)	The bankfull stage (m)	138.00	129.64
			The limited discharge (m^3/s)	2,750	2,734
		The PSP (5 ~ 6)	The bankfull stage (m)	137.90	129.54
			The limited discharge (m^3/s)	2,630	2,521
The RWP		The ISP (7 ~ 8)	The bankfull stage (m)	137.80	129.44
			The limited discharge (m^3/s)	2,518	2,362
		The TSP (9 ~ 10)	The bankfull stage (m)	138.20	129.84
			The limited discharge (m^3/s)	3,024	3,080
The RWP The DWP	Q_{L3}		The warning water level (m)	138.50	130.10
			The limited discharge (m^3/s)	3,300	3,800

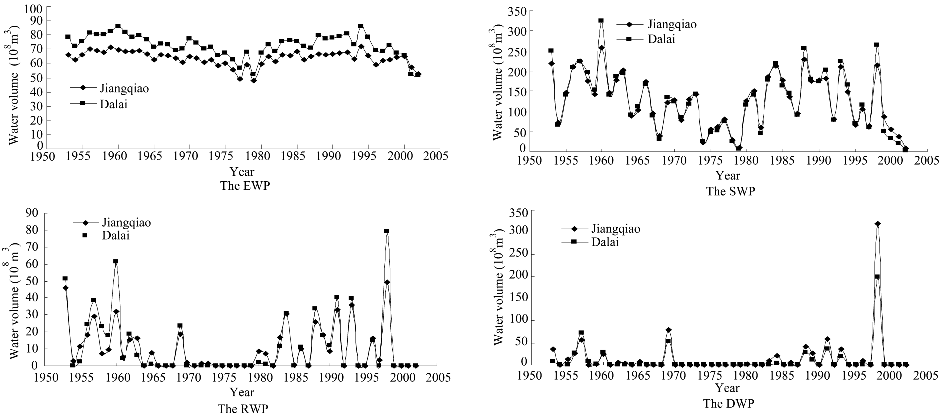

Fig. 3 The annual four water portions variation tendency of the Jiangqiao and Dalai hydrologic stations

The causes of aforementioned five points can be explained as follows: ① The highly linear correlated between the two hydrologic stations with the annual runoff. ②The EWP is the absolutely necessarily water portion for the river, which is determined from the prevention lower limit river ecosystem, the value of which is small, so the quantity of which is lesser and can be satisfied in the most time of one year. ③In the most time, the river water is below the limit boundary Q_{L2} and the proportion of which exceeds 50% , then the SWP can represent the variation tendency of the annual runoff at a certain extent. ④The RWP and the DWP only appear in the high flow years, and the difference of the annual runoff as well as their course is very apparent. ⑤ A catastrophic flood breaks out in the 1998(see Fig. 4). The flood peak is overly large and last a long time. Then the quantities of the two water portions are very high. In this year, the flood of the Jiangqiao river reach fluctuates more rapid than the Dalai, but the last time of which greater than the limit boundary Q_{L2} is less than the Dalai, then the quantity of its RWP less than the Dalai's. The distance between the Jiangqiao and Dalai is 216 km, and the river cross section is more than 10 km at majority river reach. In 1998, after the detained by the main river channel, the flood course changes gently in the Dalai river reach; in addition, the crevasse between this river reach also greatly debases the flood peak, all of them induce the DWP of the Dalai's.

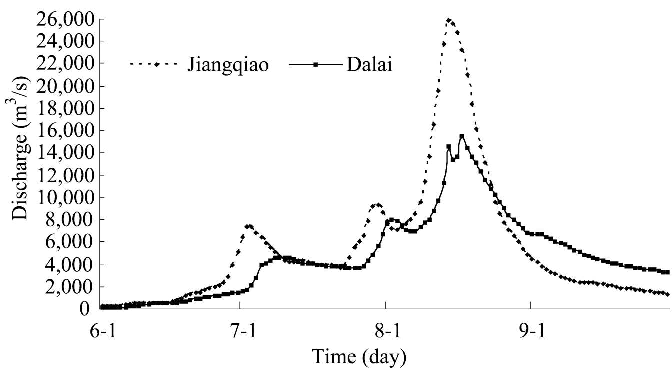

Fig. 4 The measured discharge process at the Jiangqiao and Dalai hydrologic stations in 1998

3.2 The four water portions proportion analysis of the Jiangqiao and Dalai hydrological stations

In the research period (1953 ~ 2002), the annual proportion of each water portion is likely to different with other years, even larger significance of difference. In order to research more clearly, the four water portion proportions can be analyzed according to two cases: long – time average annual value and characteristic years.

3.2.1 The long – time average annual value analysis of the four water portions proportion

The River Water Structure (RWS) of long – time average annual value of the two hydrological stations are similar (see Fig. 5). The proportions of the EWP are 30% (Jiangqiao) and 33% (Dalai) respectively. This result accords with the research conclusion of the historical flow method (Orth DJ, Leonard PM. 1990), which think that the river runoff holding in about 30% of the mean annual runoff can supply better base flow for the most aquatic organism. Because the river water be in the range of the SWP at the most time, thus the proportion (58%, Jiangqiao; 57%, Dalai) of which is maximal in the RWS. For only appearing in the high flow years, the proportions of the RWP and the DWP are relative less than other two water portions. The characteristic of the River Water Structure (RWS) is very significative for the flood protection and river water resources utilization. For the flood protection, it is not necessary to deal with the whole flood runoff, only to dispose the RWP or the DWP by some measures can satisfy the demands of which. For the river water resources utilization, it is very important how to alter the RWS according to the characteristic of which to increase the utilization ratio of the river water resources.

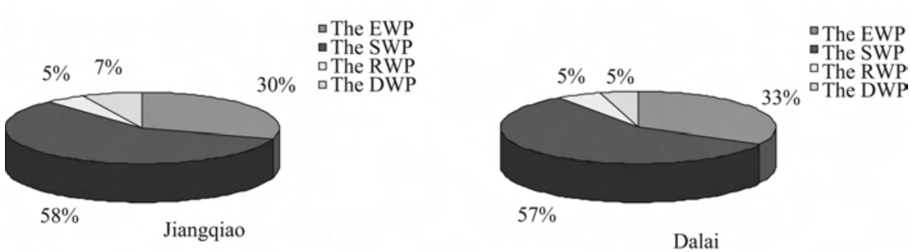

Fig. 5 The RWS of long – time average annual value of the Jiangqiao and Dalai hydrologic stations

3.2.2 Analysis on the proportion of four water portions taken by characteristic years

The characteristic years can better represent the serial years to a certain extent. According to results of the hydrologic frequency analysis, the following five type years can be selected: special high flow year (1998, 0.5%), a little high flow year (1983, 30%), common flow year (1996, 50%), low flow year (1995, 70%) and extreme low flow year (2002, 98%).

In the same characteristic year, the runoff course of the Jiangqiao and Dalai hydrologic station is similar (see the Fig. 6): in the special high flow year (1998, 0.5%), whether the runoff course or the runoff volume is remarkably greater than other type years; but in the extreme low flow year (2002, 98%), the maximal discharge of the Jiangqiao and Dalai only is 667 m^3/s and 488 m^3/s respectively.

There is a little difference between the River Water Structure (RWS) of the Jiangqiao and Dalai hydrologic stations at the same characteristic year. But in the different characteristic years, the differences of the RWS are very larger (see Table 5). The Table 5 indicates: ①In the extreme high flow year (1998, 0.5%), the RWP and the DWP sharply increase in this year, especially the DWP, the proportion of which reaches to 49% (Jiangqiao) and 32% (Dalai) respectively, much more than the long – time average annual value of which; ② In the a little high flow year (1983,

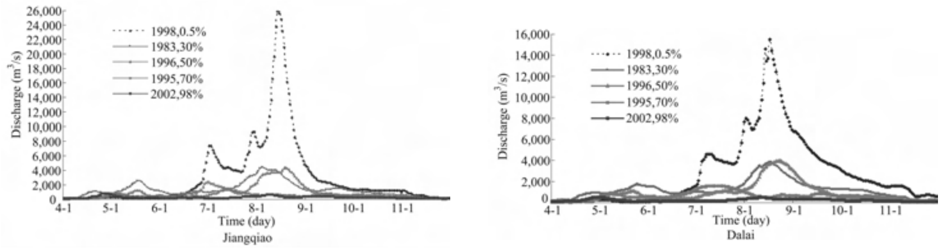

Fig. 6 The runoff course in the characteristic years of the Jiangqiao and Dalai hydrologic stations

30%), the proportion of the SWP rises obviously and the RWP and the DWP are on the small side; ③In the common flow year (1996, 50%), the EWP increases apparently, the proportion researches to 31% (Jiangqiao) and 34.72% (Dalai) respectively; ④In the a little low flow year (1995, 70%), the EWP continues to increase and doesn't appear the RWP and the DWP; ⑤In the extreme low flow year (2002, 98%), the EWP reaches to 85% (Jiangqiao) and 95% (Dalai) respectively.

The causes of aforementioned five points can be explained as follows: ①In the extreme high flow year, a catastrophic flood breaks out, as a result, the RWP and the DWP are overly greater than the long – time average annual value. Because of the crevasse between this river reach, about 9.93 billion m^3 river water branched off from the main watercourse, the River Water Structure (RWS) of the Dalai changes larger comparing with the Jiangqiao; ②In the a little high flow year, the flood intensity is much less than that of the extreme high flow year, consequently, the quantity and proportion of the RWP and DWP are smaller. Regulated by the broad river channel, the RWS gains certain changes: most DWP and part of DWP changes to other water portions; ③In the common flow year, the fluctuation of the river runoff course is relatively gentle, then the proportion of the EWP increases; ④In the a little low flow year, the river water can't reach to the bankfull stage, all the annual runoff is acted as the EWP and the SWP; ⑤In the extreme low flow year, the annual river runoff is very small, nearly all the river runoff is used to maintain the balance of the low limit ecosystem. In addition, because of the strong evaporation as well as little replenishment water, the annual runoff of the Dalai is less than Jiangqiao hydrologic station.

Table 5 The quantity of the four water portions in the characteristic years

Unit: 10^8 m^3

Hydrologic station	Characteristic year	Frequency (%)	The EWP	The SWP	The RWP	The DWP	Runoff
Jiangqiao	1998	0.5	62.56	213.27	49.11	319.12	644.06
	1983	30	66.28	185.03	16.73	9.81	277.84
	1996	50	59.3	105.26	16.14	8.67	189.37
	1995	70	65.71	66.86	0	0	132.58
	2002	98	52.41	9.24	0	0	61.65
Dalai	1998	0.5	72.49	263.18	79.21	198.57	613.46
	1983	30	75.29	177.9	11.61	0.06	264.86
	1996	50	68.93	114.37	14.68	0.57	198.55
	1995	70	78.47	69.87	0	0	148.33
	2002	98	51.68	2.63	0	0	54.32

3.3 The frequency analysis of the RWP and the DWP

The calculation results indicate that there are 33 and 24 years (Jiangqiao) appear the RWP and the DWP respectively, the frequency of occurrences of which respectively are 66% and 48%; and there are 22 and 17 years (Dalai) appear the RWP and the DWP respectively, the frequency of occurrences of which respectively are 48% and 34%. All of which indicate that the flood disaster break out with a high frequency in the Songne Plain. All the DWP of the Jiangqiao are greater than the Dalai's in the same year (see Table 6).

Table 6 The RWP and the DWP list of the Jiangqiao and Dalai hydrologic stations

Unit: billion m^3

Years		1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963
Jiangqiao	The	46.14	2.68	11.62	18.17	29.25	7.28	9.79	32.05	5.18	15.55	16.16
Dalai	RWP	51.31	0	2.29	24.46	38.34	23.15	17.95	61.17	4.45	18.46	6.22
Jiangqiao	The	36.24	0	12.98	27.22	57.66	0.31	1.03	24.49	0.03	6.38	3.2
Dalai	RWP	7.39	0	0	25.95	72.69	7.89	2.7	29.19	0	0.92	0
Years		1965	1966	1969	1970	1972	1973	1980	1981	1983	1984	1985
Jiangqiao	The	7.46	0.18	18.46	2.09	1.23	1.36	8.48	7.17	16.73	30.46	0.68
Dalai	RWP	1.15	0	23.25	0	0	0	2.09	0.82	11.61	30.67	0
Jiangqiao	The	6.73	0	80.17	0	0	0	1.88	0.69	9.81	20.3	0
Dalai	RWP	0	0	52.94	0	0	0	0	0	0.06	3.89	0
Years		1986	1988	1989	1990	1991	1992	1993	1994	1996	1997	1998
Jiangqiao	The	9.88	25.76	17.96	8.42	32.87	0.1	36.12	0.16	16.14	3.38	49.11
Dalai	RWP	10.82	33.38	17.74	11.78	40.41	0	39.54	0	14.68	0	79.21
Jiangqiao	The	5.87	41.16	27.38	0.45	59.01	0	36.78	0	8.67	0	319.12
Dalai	RWP	0	27.45	11.21	0.36	36.71	0	19.86	0	0.57	0	198.57

Moreover, in the years Jiangqiao appearing the RWP without the DWP, the quantity of the RWP is relatively less, the quantity value of which is less than 0.4 billion m^3, at the same time Dalai neither appearing the RWP nor the DWP, such as 1954, 1966, 1970, 1972, 1973, 1985, 1992, 1994 and 1997 (see Table 6), which indicates that after regulated by the river channel, the RWP of the upstream has changed into other water portions (the EWP or the SWP), thus the appearing frequency of the RWP and the DWP at the Dalai hydrologic station are less than the Jiangqiao's. The table 6 indicates that the DWP quantity of which general is small, some measures can be taken to change it into other water portions. However, in some catastrophic flood years, the quantity of which can reach a very larger value, such as in 1998, the DWP quantity of the Jiangqiao and Dalai reach to 31.92 billion m^3 and 19.857 billion m^3 respectively.

4 Conclusions

The theory of the River Water Structure (RWS) provides a new idea for the river water resources optimal distribution. Base on the RWS theory, proper methods are selected to determine the limit boundaries between the different water portions, then the quantity of each water portion can be calculated out, which can be logically deal with according to the practical conditions to decrease the water shortage.

Although there are not the natural conditions on the downstream of the Nenjiang River to erect the hydro – junctions, lots of lake marshes distribute on the Songnen Plain, which can be used to regulate the river flood water. According to the characteristic of the river runoff, the partial or entire of the DWP and RWP even the SWP can be regulated by the flood retarding basin following certain regulations. With the changing of the RWS, the river ecosystem balance can be better guaranteed.

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Effect of the Xiaolangdi Reservoir Operation on Maintaining the Healthy Yellow River in Shandong Province

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Abstract: Xiaolangdi Reservoir stores water since Oct, 1999 and operates since 2000. Because of the regulation of the reservoir , the condition of water and sediment had obvious changed, the inter – annual variation decreased, the distribution evened in all year, flood peak volume decreased, the duration of middle and small scale flood increased and the sediment concentration decreased. After five years consecutive water and sediment regulation and the autumn flood scouring in 2003 and 2005, the flood carrying capacity of lower reaches of the Yellow River had been obvious improved, and the river stabilized and developed to the better way. The operation of Xiaolangdi reservoir had important effect on maintaining the Yellow River Healthy in Shandong province.
Key words: Regulation of water and sediment, scouring and silting, Xiaolangdi Reservoir, the Yellow River Healthy

After Xiaolangdi Reservoir stores water since Oct,1999, its capability of regulating water and sediment increased, the condition of water and sediment and the movement of flood had obvious changed and the flood carrying capacity of lower reaches of the Yellow River had obvious renewed. Analysis on the characteristic of water and sediment and the rules of flood evolution can make important and instructive meaning on strategic decision – making of maintaining the Yellow River Healthy in Shandong Province, flood control, water regulation and project construction.

1 The effect of the Xiaolangdi Reservoir operation and regulation of water and sediment

Xiaolangdi Reservoir stores water since Oct, 1999 and operates since 2000, regulates water and sediment and holds up flood since July to September, stores water for generating electricity, irrigation and making flood peak to scour river channels in lower reaches of the Yellow River. There were actually no regulations for flood control because there was less water came from upper and middle reaches of the River in 2003 and 2005. There were five times of man – made water and sediment regulations and actual autumn flood regulations in 2003 and 2005. In the operating period, the highest water level was 265. 58 m(Oct, 15 th,2003) , the most flux is 3,996 m^3/s(Jun, 22 th, 2005) , the average most sediment concentration during the period of flood is 104. 7 kg/m^3 (Sep, 2003) and the least is 0. The detail is as follows:

The first regulation of water and sediment occurred in July, 2002. The experimentation began at 8a. m. on Jul, 4th, that the water level is 236. 54 m and the relevant water storage is 44. 0 billion m^3, and ended at 8a. m. on Jul, 18th, that the water level is 222. 01 m and the relevant water storage of the Xiaolangdi Reservoir is 25. 9 billion m^3. The flow peak is 3,480 m^3/s, the total water amount discharged into the downstream of the Yellow River is 28. 5 billion m^3, the sediment amount is 0. 321,0 billion t, the average sediment concentration is 11. 3 kg/m^3. There were larger rainfall in the Yellow River basin in 2003 and abundant flood in Wei River, Yiluo River and Qin River and the associated long – distance regulation between Xiaolangdi Reservoir and Luhun, Guxian, Sanmenxia Reservoirs, lowered the flood peak, lightened the stress of flood control of the Lower Yellow River, and avoided large – scale floodplain damage and reduced the people' s Loss. During flood control period of the Xiaolangdi Reservoir, the highest water level is 265. 58 m(14 p.

m. Oct,15th), the relevant water storage is 95.20 billion m^3, the peak flow is 2,540 m^3/s, the total water amount is 106 billion m^3, the sediment amount is 1.2 billion t, the average sediment concentration is 11.3 kg/m^3. In 2004, the regulation of water and sediment of Xiaolangdi Reservoir started at 9a. m. on Jun, 19th, ended on Jul, 18th, lasting 29 days. The water level of the Xiaolangdi Reservoir fell from 249.06 m to 225.00 m, declined 24.06 m, the water storage reduced 33.0 billion m^3, the most discharge is 2,940 m^3, the total discharge is 44.51 billion m^3. In 2005, the pre – discharge of flood control period of Xiaolangdi Reservoir started on Jun, 9th, ended Jul, 6th, lasting 28 days. The water level of the Xiaolangdi Reservoir fell from 252.17 m to 224.81 m, the water storage reduced 39.40 billion m^3, the most discharge is 3,996 m^3/s, the total discharge is 51.87 billion m^3. In 2006, the regulation of water and sediment of Xiaolangdi Reservoir started on Jun, 10th, ended on Jun, 29th, lasting 19 days. The water level fell from 254.05 m to 224.51 m, declined 29.54 m, the water storage fell from 62.29 billion m^3 to 19.58 billion m^3, reduced 42.71 billion m^3, the most discharge is 4,200 m^3/s, the total discharge is 54.46 billion m^3.

2 The characteristics of water and sediment in Shandong province after the operation of Xiaolangdi project

Since the operation of Xiaolangdi Reservoir, the lower Yellow River entered low flow and low sand period because there was little rainfall in the Yellow River Basin. The water and sand both became fewer and the sand even more few comparing with before. The percent of the water and sand in flood season decreased, but in non – flood season this percent increased, as a result, the percent of water and sand became. even in whole year.

2.1 The annual variation decreased, and the coming water and sand belongs to low flow and few sand series

From 2000 to 2006, The biggest and smallest measured discharge in Gaocun is 257 billion m^3 (2003) and 130 billion m^3 (2001), which means 2.0 times. The biggest and smallest measured sediment concentration is 2.75 billion t (2003) and 0.841 billion t (2001), which means 3.3 times. The biggest and smallest measured flow in Lijin is 207 billion m^3 (2005) and 41.9 billion m^3 (2002), gap reaches 5.0 times. The most and least metrical annual sediment concentration is 3.7 billion t (2003) and 0.191 billion t (2005), gap reaches 19 times. The inter – annual variation has minished obviously comparing with the average of years.

Drom 2000 to 2006, the average runoff in Gaocun is 193 billion m^3 and decreased 49% comparing with 379 billion m^3 in 1951 ~ 1999. The average sediment concentration of six years in Gaocun is 1.66 billion t and decreased 82% comparing with 9.38 billion m^3 in 1951 ~ 1999. The average runoff of six years in Lijin is 123 billion m^3 and decreased 64%, comparing with 338 billion m^3 in 1951 ~ 1999. The average sediment concentration of six years of Gaocun is 1.53 billion t and decreased 82% comparing with 8.50 billion m^3 in 1951 ~ 1999.

2.2 The distribution of water and sand evened in whole year

From 2000 to 2006, the average discharge in flood season of six years in Gaocun is 79.9 billion m^3 and the water in flood period falls from 57% to 41%, the average runoff in non – flood season of six years in Gaocun is 11.3 billion m^3 and the percent rises from 43% to 59%. The average sediment concentration in flood season of six years in Gaocun is 0.101 billion t and the percent falls from 80% to 61%, the average sediment concentration in non – flood season of six years in Gaocun is 0.0656 billion t and the percent rises from 20% to 39%.

From 2000 to 2006, the average flux in flood season of six years in Lijin is 6.7 billion m^3 and the percent falls from 61% to 55%, the average flux in non – flood season of six years in Lijin is

5.52 billion m^3 and the percent rises from 39% to 45%. The average sediment concentration in flood season of six years in Lijin is 0.114 billion t and the percent falls from 85% to 75%, the average sediment concentration in non – flood season of six years in Gaocun is 0.038,6 billion t and the percent rises from 15% to 25%.

2.3 The sediment concentration decreased obviously

The sediment concentration is lower because of the storing water and holding sand of the Xiaolangdi Reservoir. The average sediment concentration of six years in Gaocun is 8.63 kg/m^3 and decrease 65% comparing with the average of years, thereinto, the average in flood season is 12.6 kg/m^3 and decreases 64% comparing with the average of years. The average sediment concentration of six years in Lijin is 12.4 kg/m^3 and decreases 51% comparing with the average of years, thereinto, the average in flood season is 16.9 kg/m^3 and decreases 52% comparing with the average of years.

3 The scouring and silting of Shandong Yellow River Channel after the operation of Xiaolangdi Reservoir

Based on the result of scouring and silting survey through Cross – section method (Table 1), in the first operation year (Oct. 1999 ~ Oct. 2000), the amount of silting is 0.202×10^8 m^3 in Gaocun – Qing7 and the amount of scouring is 5.4×10^6 m^3 in Luokou – Lijin. In the second operation year (Oct. 2000 ~ Oct. 2001), the amount of silting is 0.129×10^8 m^3 in Gaocun – Cha2 and the amount of scouring is 0.038×10^8 m^3 in Sunkou – Luokou because of the influence of "01.8" adding water from Dawenhe, other reaches were silted, but the amount of silting in Gaocun – Sunkou reduces obviously which make clear that clean water discharging from the Xiaolangdi affects this reach. In the third operation year (Oct. 2001 – Oct. 2002), the amount of scouring is 0.038×10^8 m^3 in Gaocun – Cha2 in non – flood season, except the amount of silting is 0.044×10^8 m^3 in Sunkou – Luokou, other reaches scouring, the amount of scouring is 0.544×10^8 m^3 in flood season, the amount of scouring is 0.582×10^8 m^3 in the chief channel in Gaocun – Cha2, all chief channels were scoured. In the fourth operation year (Oct. 2002 ~ Nov. 2003), the amount of silting is 0.037×10^8 m^3 in Gaocun – Cha2 in non – flood season, the amount of scour is 1.09×10^8 m^3 in Gaocun – Aishan in flood season because of the action of long – time autumn flood, the amount of scouring is 1.05×10^8 m^3 in all year; In the fifth operation year (Nov. 2003 ~ Oct. 2004), the amount of silting is 0.129×10^8 m^3 in Gaocun – Cha2 in non – flood season, the amount of scouring is 0.490×10^8 m^3 in flood season, the amount of scouring is 0.361×10^8 m^3 in all year. In the sixth operation year (Oct. 2004 ~ Oct. 2005), the amount of scouring is 0.808×10^8 m^3 in Gaocun ~ Cha2, the amount of scouring in non – flood season and flood season is 0.016×10^8 m^3 and 0.792×10^8 m^3 respectivly. Considering the scouring and silting route in non – flood season, it has the characteristic of "scouring in upper and silting in lower", but the absolute value is small. In the seventh operation year (Oct. 2005 ~ Oct. 2006), the amount of scour is $0.116,7 \times 10^8$ m^3 in Gaocun – Cha2, the amount of silting in non – flood season and scouring in flood season is $0.203,1 \times 10^8$ m^3 and $0.319,8 \times 10^8$ m^3.

Since the six years operation of Xiaolangdi project, the amount of scouring is $2.586,4 \times 10^8$ m^3 in Gaocun – Cha2. Along the River, the percent of scouring is 25.9% in Gaocun – Sunkou, 11.8% in Sunkou – Aishan, 19.9% in Aishan – Luokou, 30.9% in Luokou – Lijin, 11.5% in Lijin – Cha2. In the period, silting is the main effect in flood and non – flood season in Gaocun – Cha2 during Oct. 1999 to Oct. 2001, scouring is the main effect during Oct. 2001 to Oct. 2005 and the maximal is in 2003 and 2005, the percent being 42.0% and 30.6%.

Table 1 The amount of scouring and silting after Gaocun During 2000 ~ 2005

Period	Gaocun – Sunkou ($10^8 m^3$)	Sunkou – Ai'shan ($10^8 m^3$)	Ai'shan – Loukou ($10^8 m^3$)	Luokou – Lijin ($10^8 m^3$)	Lijin – cha2 ($10^8 m^3$)	Gaocun – cha2 ($10^8 m^3$)
1999.10 ~ 2000.10	0.164	0.002,2	0.016,6	−0.005,4	0.024,2	0.201,6
2000.10 ~ 2001.10	0.085,4	−0.015,5	−0.022,3	0.041,3	0.039,9	0.128,8
2001.10 ~ 2002.10	−0.190,1	−0.014,2	−0.044,9	−0.187,2	−0.145,1	−0.581,5
2002.10 ~ 2003.11	−0.233,1	−0.100,9	−0.215,4	−0.310,1	−0.190,1	−1.049,6
2003.11 ~ 2004.10	−0.051	−0.052,8	−0.120,5	−0.148,8	0.012,1	−0.360,9
2004.10 ~ 2005.10	−0.229,7	−0.122,9	−0.202,7	−0.151	−0.101,8	−0.808,1
2005.10 ~ 2006.10	−0.214,5	−0.000,6	0.073,6	−0.037,9	0.062,7	−0.116,7
1999.10 ~ 2006.10	−0.669	−0.304,7	−0.515,6	−0.799,1	−0.298,1	−2.586,4

4 Analysis on the effect of the Xiaolangdi Peservoir operation on maintaining the Healthy Yellow River in Shandong Province

4.1 the passing capability of main chamel had obvious enlarged

In the five regulation of water and sediment, there were 3.56×10^8 t sediment transported to ocean and scoured 0.913×10^8 t in Shandong, so the river channel deepened universally, the average discharge increased from 1,800 m^3/s (in Heze) in 2002 to 3,500 m^3/s and the passing capability of main channel enlarged and the discharge of 3,750 – 3,900 m^3/s can pass successfully.

4.2 the water level in same discharge reduced obviously

The water level of 3,000 m^3/s in all Shandong stations in 2006 reduced obviously compared to the preliminary period in 2002 and reduced 0.88 m in average, thereinto, the most is 1.26 m in Gaocun, the least is 0.64 m in Lijin (see Table 2). After the regulation of water and sediment, the water level in same flow, 3,000 m^3/s, reduced most in 2003 because the autumnal flood last in 3,000 m^3/s three months in lower reaches of the Yellow River, the river channel scoured acutely and the water level in 3,000 m^3/s reduced 0.48 m in average.

4.3 The river regime in lower reaches developed to the better way

After five regulations of water and sediment, the time of overflow occurring in Shandong reach prolongs evidently, the ability of current creating riverbed boosts up, and river channel becomes straight and steady. The flexuous river channel due to the few – water in 1990s is adjusted and the disadvantageous complexion that most project crook and sink is improved. Advantageous condition of water and sediment accelerates the adjustment and perfection of river regime.

4.4 The time of emergency reduced plentifully

The data of project emergency during the regulation of water and sediment period from 2002 to 2006 show that project emergency reduced year after year in general. There are 417 dams, 528 emergencies and using 83,713 m^3 stone in 2002; 467 dams, 519 emergencies and use 73,936 m^3 stone in 2003; and 105,39,103 dams, 121,43,127 emergencies and use 29,685 m^3, 7,666 m^3, 21,410 m^3 stone in 2000 ~ 2006. During the period, the base of the River project was reinforced continuously and the capability to keeping out flood boosted up continuously. Under ordinary flood only slight footstone missing and collapse occurred.

Table 2 The water level in same discharge, 3,000 m^3/s, after flood season

Unit: m

time	Gaocun	Sunkou	Ai'shan	Luokou	Lijin
2002	63.70	49.08	42.06	31.34	14.12
2003	63.11	48.78	41.46	30.93	13.62
2004	62.65	48.58	41.35	30.80	13.35
2005	62.50	48.58	41.04	30.42	13.26
2006	62.44	48.35	41.14	30.50	13.48
2002 ~ 2006	-1.26	-0.73	-0.92	-0.84	-0.64

4.5 The Yellow River estuary wetlands restored obviously

The Yellow River estuary wetlands are the most perfect and the widest and youngest wetlands ecosystem in China Temperate Zone and fresh water is the foremost ecological factor to the Yellow River estuary wetlands. In the past, because of intense exploiture and water shortage, the wetlands area reduced and the water condition deteriorated, many badlands appeared. In the near five years, through scientific regulation of water and sediment, there is no zero - flow of the Yellow River and the water supplies to wetlands. The trend of wetlands area reduce and salinity is alleviated. The wetland is renewed and expanded. The environment is improved. Now, the total area of wetland in the Yellow River Delta is near to 2.0×10^5 hm^2, the coastline boosts 1.6 km to the ocean and the wetland area adds 2.0×10^4 ha only through the fourth regulation in 2005.

5 Conclusions

Since the operation of Xiaolangdi Reservoir, through continuous regulation of water and sediment of five years, the flood carrying capability of the lower Yellow River had obvious been improved. The water level in same flow falls obviously, the average capacity increased from less 2,000 m^3/s to 3,500 m^3/s. Now, the passing capability of reaches had obvious been improved compared with the period before flood season in 1996, the river channels stabilized and developed to the better way, the wetlands renewed and expanded and the environment had been improved. So the operation of Xiaolangdi Reservoir had important effects on maintaining the Healthy life of the Yellow River in Shandong Province.

The Ecological Environment Current Situation and the Restoration Evaluation of the Groundwater System in Beneficiary Region of Water Transfer Project from South to North

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Abstract: The water received area of South – to – North Water Transfer Project (SNWTP) covers six provinces and municipalities including Beijing, Tianjin, Hebei, Henan, Shandong and Jiangsu. This region holds the important strategic position in Chinese social – economic development and food safety. Influenced by the climate change, increasing population and economy development, the water received area sustain its region development by continuous groundwater exploitation, which has caused a series of ecological environment problems, such as groundwater exhaustion cones caused by the partly aquifer dewatering, land fracture caused by the unevenly land subsidence and salty fresh water layer caused by the sea water intrusion, etc. All these problems have limited the region economy development. According to the groundwater overwithdrawal reduction scheme of the SNWTP' beneficiary region, groundwater overwithdrawal reduction rate in water received area in 2020 will reach 60%. This will make the groundwater tables, the aquifer reserves and the land subsidence develop into a good direction. Therefore, the SNWTP will not only have the significant importance in improving the beneficiary region's social economy development, but also have the remarkable effect in improving the regional ecological environment situation.
Key words: South – to – North Water Transfer, beneficiary region, groundwater, ecological environment, restoration

The South – to – North Water Transfer Project (SNWTP) is a tremendous large – scale water resources allocation project aiming at resolving the water resources shortage in north China. Implementation of this project will significantly change the water condition and water resources allocation pattern in the Huang – Huai – Hai region in China, and will also promote the regional groundwater overwithdrawal reduction and create favorable condition for the groundwater ecological system restoration. Based on the groundwater overwithdrawal reduction scheme of the SNWTP beneficiary region worked out by MWR, this paper illustrates the ecological environment problems caused by the water over – exploitation in the water received area, and make an overall evaluation of the groundwater restoration system of the water received area after the water transferred by the SNWTP.

1 The general situation of the SNWTP's beneficiary region

The water received area of the first phase of the SNWTP is from the Nanyang Basin in Henan Province in the south, to the Beijing and Tianjin Plain in the north, and from Jingguang Railway in the west, to the Shandong Peninsula and coastal area in Hebei Province in the east. The whole area is 233,200 km^2, covering 38 cities and municipalities in Beijing, Tianjin, Hebei, Shandong, Henan and Jiangsu Province.

West of the water received area is almost the alluvial plain out of the mountain, and east of the area is the coastal plain, which is plainness and inclined from south – west to north – east. The water received area belongs to the half – humid monsoon climate, and has the characteristics of drought and windy in the spring, hot and rainy in the summer, sunny and cool in the autumn and cold and dryness in the winter. The annual mean precipitation declines from south to north, for example, the maximum precipitation is in the south Henan Province which is about 800 ~ 900 mm, while the minimal precipitation is in the middle of Hebei Plain which is about 450 ~ 500 mm. The yearly precipitation is variable greatly, and its allocation in one year is unevenly. The maximum precipitation in the rainy year is two or three times than the minimal precipitation in the drought year, and the precipitation in the flood season accounts for 60% ~ 80% of the year total precipitation.

The water received area has a large number of population, plenty of big and middle cities, developed economy and quick developing speed. According to the statistics in 2004, the population of Beijing, Tianjin, Hebei, Henan, Shandong and Jiangsu has reached 149 millions, which is 11.5% of the whole country's population. This area is also the main food production area in China. Its food output and GDP account for 14.2% and 16.4% respectively of that of the whole country. The 6 provinces and municipalities involved in the water received area hold the important strategic position in the country's economic and social development and food safety.

The annual mean actual groundwater exploitation of the shallow layer in the whole water received area added up to 22.3 billion m^3 during 1999 to 2003. The exploitation ratio is as follows: urban living is 6%, rural living is 8%, industry is 14% and agriculture is 72%. The annual mean actual groundwater exploitation of the deep confined layer in the whole water received area added up to 4.84 billion m^3. The exploitation ratio is as follows: city living is 9%, rural living is 12%, industry is 29% and agriculture is 50%. Agriculture is the main user of the exploited groundwater in all the industries.

2 The over – exploitation situation of the groundwater in water received area and its caused ecological environment problems

Over – exploitation of the groundwater means the groundwater exploitation exceeds the possible permitting exploitation, and resulted in the continual groundwater table declining or the environmental geological disaster and ecological environmental deterioration. The total shallow layer over – exploited groundwater area in the water received area is 57.7 thousand km^2, which is 25% of the whole water received area. The proportion of the over – exploited area in the whole water received area is high in Beijing and Hebei and the shallow layer groundwater in most of the Hebei province's water received area is over – exploited. The current total deep layer over – exploited groundwater area in the water received area is 73.7 thousand km^2, which is 32% of the whole water received area. Most of the deep confined groundwater in Tianjin is over – exploited, and the deep confined over – exploited groundwater area in Hebei province accounts for about 60% of its water received area. So, the water received area is now facing the serious over – exploitation problems, especially in two provinces and one municipalities, which are Hebei, Henan and Tianjin.

Due to the quick development of the social economy and the natural condition limitation such as the climate and precipitation, the groundwater in the water received area was over – exploited for a long time in order to sustain the development, which has caused various ecological and environmental problems. According to the arousing mechanisms, these ecological and environmental problems can be classified into partly dewatering of aquifer and sea water intrusion caused by the over – exploited shallow layer groundwater, and the deep layer exhaustion cone, land subsidence, land fracture caused by the over – exploited deep layer groundwater.

2.1 Ecological and environmental problems caused by the shallow layer groundwater over exploiting

Partly dewatering aquifer. This kind of problem can be found in both Beijing and Hebei province. Up to 2003, the groundwater exhaustion cone area in Beijing has extended to 908 km^2, mainly distributed in the line from Jiangtai in Chaoyang district to Migezhuang in Shunyi county. In the area of thinner Quternary sediment, the aquifer is now facing the dewatering and half – dewatering problems. In 2003, there were 11 shallow layer groundwater cones in Hebei plain, and the total cone area is 3,133 km^2, in which the Shijiazhuang cone and Ningbailong cone has the greatest influences. The middle water table in some cones has been lower than the first layer floor elevation. According to under – statistics, the plain dewatering area in front of the Taihang Mountain has reached 1,700 km^2.

Sea water intrusion. The water received area faces Bohai and Huanghai in the east, and the over – exploitation of shallow layer groundwater has led to the sea water intrusion in many places. For example, in the Laizhou Gulf in Shandong, the sea water intrusion was intensified during 1985 to 1997 because of the over – exploitation of the groundwater. Therefore, in 1997, the sea water intrusion area in this city has reached 277 km^2. It is the quick development period of sea water intrusion in Laizhou city, and the annual mean intrusion speed has reached 200 m. Up to 2003, the sea water intrusion area in the city has reached 234 km^2. Other districts around the Bohai Gulf have the same problem of sea water intrusion or mixing of sea water and fresh water caused by the exploitation of the shallow layer groundwater. These problems have led to the serious influence on living water use and production water use.

2.2 Ecological and environmental problems caused by the over – exploitation of deep confined water

The over – exploitation has formed the confined water exhaustion cone. The serious over – exploitation of deep confined water happened in Tianjin, Hebei and partly in Henan. There are 7 deep confined water exhaustion cones in middle – east plain of Hebei, and the cone area is about 44,000 km^2. Among them, the Jizaoheng cone and Cangzhou cone have the greatest effect and have lasted for the longest time. They are developed from the end of 1960's to the beginning of 1970's.

The over – exploitation has caused the land subsidence. Due to the continuous over – exploitation of deep confined water, various types of land subsidence have been found in Tianjin, Hebei, Jiangsu and Henan. Up to 2000, the land subsidence area in Tianjin has reached 8,000 km^2, and the biggest accumulated subsidence value is 3040mm. It is very obvious in the south and the coastal area, and this area combined with Hebei has formed a large subsidence area. The most serious subsidence region in Hebei is the middle – east plain. There have been 8 high subsidence value regions in Hebei, that is Cangzhou, Renqiu, Bazhou, Langfang, Baoding, Hengshui, Nangong, Feixiang and so on. Among them, Cangzhou and Renqiu are the most serious regions. Up to 2003, the biggest accumulated subsidence value is 2 m. The area where its accumulated subsidence value is more than 300 mm in the 8 subsidence areas has reached 11,833.9 km^2, area that the subsidence value more than 500 mm has reached 2,833.5 km^2, and area that the subsidence value more than 700 mm has reached 620.9 km^2.

The uneven subsidence led to land fracture. According to the investigation results in Hebei province, the land fracture length of Shuibo Primary School in Jianguo town, Gucheng county is 138 meters long and 1meter wide; the land fracture length of Guancun village, Manhe town, Fucheng county is 100 meters long and 3 meters wide. Though the land fracture is not caused totally by groundwater over – exploitation, the over – exploitation of groundwater promotes, to some extent, the development of land subsidence and land fracture.

3 Groundwater restoration evaluation in water received area of SNWTP

3.1 The overwithdrawal reduction degree defined by the groundwater overwithdrawal reduction scheme

According to the guideline of general plan of SNWTP, the principle of groundwater overwithdrawal reduction is to controll firstly the city water use then village, controll firstly the industry water use then agriculture, controll firstly the deep confined water exploitation then shallow layer groundwater. Based on the future water supply and demand analysis of the water received area, considering comprehensively the transferred water, local surface water, groundwater, reused water, desalination water and other water source that can substitute the over - exploited water, the groundwater overwithdrawal reduction quantity in various phase is determined. The SNWTP has obvious phases from its construction phase, its water transferring phase, to its final phase. In this paper, the positive effects of the project on the groundwater system in the water received area after the project has completed was especially analyzed.

According to the groundwater overwithdrawal reduction scheme, considering the project's first phase water supply, in 2020, the situation of shallow layer groundwater and deep confined water of each province in the water received area is as follows: the overwithdrawal reduction degree of deep layer water is higher than that of the shallow layer. Current over - exploitation in Tianjin, Shandong, Jiangsu can be all controlled, while in Beijing, Hebei and Henan, there is still some over - exploitation, in which Hebei is the most serious over - exploited province (see Table 1).

Table 1 The planning quantity of groundwater overwithdrawal reduction in the water received area of the east and middle route in the SNWTP in 2020

Unit: overwithdrawal reduction quantity, 0.1 billion m^3; overwithdrawal reduction ratio, %

District	Beijing	Tianjin	Hebei	Henan	Shandong	Jiangsu	Total
Overwithdrawal reduction quantity of the upper layer	4.0	—	14.8	5.4	4.5	—	28.7
Overwithdrawal reduction quantity of the deep layer	—	3.0	12.8	6.1	2.4	1.2	25.6
Overwithdrawal reduction ratio of the upper layer	68.4	—	40.0	57.9	110.4	—	51.0
Overwithdrawal reduction ratio of the deep layer	—	170.9	52.8	85.9	100.0	168.5	70.5

Note: overwithdrawal reduction ratio is the percentage of the overwithdrawal reduction quantity accounting for the actual over - exploitation quantity. "—" means it has no this item.

3.2 Groundwater system restoration evaluation in water received area of SNWTP

After implementation of groundwater overwithdrawal reduction scheme of SNWTP, groundwater table in most of the water received area will be elevated gradually, especially in the town and district to which transferred water will directly supply. The land subsidence, land fracture and groundwater pollution caused by the former aquifer dewatering will be controlled obviously.

3.2.1 Forecast of the groundwater table restoration effect in water received area

Under considering only the first phase water supply of east and middle route of SNWTP, the groundwater over - exploitation will all be controlled in Tianjin, Shandog, Jiangsu water received area in the future, and the groundwater table will be elevated to certain extent. The over - exploited groundwater in Beijing, Hebei and Henan province will also be controlled to some extent, the overwithdrawal reduction degree is 69%, 45% and 73% respectively (Table 1).

Forecasted by Beijing city, after the 1.05 billion m^3 water is transferred by the project, the annual mean water exploitation will be confined in 0.4 billion m^3 in city, 1.5 billion m^3 in the suburbs, then after the continuous normal flow year, forecasted groundwater table in 2020 will elevated to about 20 m deep in city, and 15 m deep in suburb. But if the coming year is continuous low flow year, the forecasted groundwater table will continuously decline. In 2020, the forecasted groundwater table in city will be 40 m deep, and 35 m deep in suburb.

3.2.2 Restoration effect analysis of the groundwater reserve in water received area

According to the groundwater overwithdrawal reduction scheme, under the premise that without other influencing factors and considering only the overwithdrawal reduction effect, in 2020, annual groundwater reserve in water received area will increase about 5.4 billion m^3 because of the decreased groundwater exploitation if compared with current exploitation degree. Among the 5.4 billion m^3, the annual shallow layer groundwater will increase 2.87 billion m^3, and the annual deep confined water will increase 2.56 billion m^3.

3.2.3 The land subsidence trend will be mitigated

The land subsidence is the most important geological hazards in Tianjin, and it has been the important limitation factor to Tianjin's economy development. Up to 2020, in Tianjin, the groundwater will not be over – exploited, the groundwater table will elevated and the land subsidence speed will decline Land subsidence in part of Tianjin will keep certain rate and last for several years according to the forecast because the land subsidence is always lagged behind the groundwater table change.

In conclusion, we forecasted that in the over – exploited region, the groundwater table will effectively elevated through the groundwater overwithdrawal reduction, local water resources reserve and its anti – drought capability will be intensified, and the sea water intrusion, land subsidence, groundwater pollution and other ecological environmental problems in some regions will be effectively improved. thus, the local ecology and environment will be gradually improved and restored, and the rational allocation of water resources and its high efficient utilization will be realized. We can say that the SNWTP will not only create the condition for the control and reduction of the groundwater exploitation in the water received area, thus promote the groundwater system restoration, but also create social and economical benefits for the water received area through groundwater overwithdrawal reduction.

Emergency Plan Formulation and Application of Yellow River Water Allocation in Shandong Province

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Abstract: In order to maintain the normal working order of Yellow River water allocation in Shandong Province and respond to the contingent incident timely, "Emergency Plan of Yellow River Water Allocation" is formulated according to the relevant national laws and regulations, combining with the real situation of Shandong Yellow River water allocation in order to ensure the Yellow River flow unceasingly. It has been put into practice and its obvious effects have been achieved. This paper would introduce the emergency plan in background, basis, incident classification, disposal measures and application effects, which can be served as reference for the Yellow River water allocation and some other rivers.

Key words: Shandong Yellow River, water resources regulation, emergency plan, application

1 Formulating Background of emergency plan

As the economy develops rapidly in Yellow River Region and the requirement of water resource for Yellow River increases gradually, the diverting water from the Yellow River has exceeded the limit of Yellow River water resource, which is more obvious in the end of the ninetieth. The flow – break of Yellow River occurs every year, which results in great economic losses for the industry and agriculture in the downstream area of Yellow River, and it has negative impacts on drinking water supply in urban & rural areas and ecological environment. In Dec. 1998, National Planning Committee and Ministry of Water Resources issued "Annual Allocation of Yellow River available Water & Water Quantity Allocation of Main Stream" and "Managing Methods of Yellow River Water Allocation", and they authorized Yellow River Conservancy Committee to manage it. Yellow River Shandong Bureau, as the supervising department of Yellow River water resources in Shandong Province, is taking various measures to strengthen the Yellow River water resources unification and allocation, which lasts seven years without stop and did achieve remarkable social, economic and ecological benefits.

As the new proposal "Maintain the Yellow River Healthy and Alive" is brought forward, higher new demands are put forward with regard to the Yellow River water allocation. No flow – break occurrence of Yellow River is not merely in physical significance and the possibility of contingent emergency occurrence increases gradually under the same conditions. In order to establish a long – term system for water quantity allocation, face and respond to the contingent incidents efficiently and rapidly and keep calm when meeting incident, it is important to formulate "Emergency Plan of Yellow River Water Allocation in Shandong Province".

2 Formulating basis of emergency plan

In the early 2006, when formulating the "Emergency Plan of Yellow River Water Allocation in Shandong Province" the "Water Allocation Regulations of Yellow River" have not come into being. The basis is according to the relevant laws and rules, such as "Water Law of the People's Republic of China", "Managing Method of Yellow River Water Allocation" etc. In Aug. 2006, after the State Council issued "Yellow River Water Quantity Allocation Regulations", the emergency plan was made complementation and improvement.

3 Classification of emergent regulation

3.1 Emergent drought condition

Drought is serious along Yellow River region in Shandong Province, which makes the water coming from upstream area insufficient for both industry and agriculture in urban & rural area. The contradiction between supply and demand is particularly prominent and no – flow situation becomes much severe.

3.2 Control cross – section discharge decrease to early – warning discharge

3.2.1 First kind of emergent incident

According to the channels water regime analysis, it is predicted that the hydrological control section discharge of the main stream may reach early – warning discharge in the future three days (early – warning discharge is identified on the bases of discharge category of Yellow River Conservancy Commission).

3.2.2 Second kind of emergency incident

The hydrological control section discharge of the main stream suddenly or nearly reaches the early – warning flow.

3.2.3 Third kind of emergent incident

The intakes along the Yellow River are exposed to artificial disturbance or mechanic disorders accidentally, which leads to the diverting water quantity increase, and results in the early – warning discharge in the downstream.

4 Disposal measures

4.1 Emergent drought condition

According to the relevant rules of "Yellow River Water Quantity Allocation Regulations", when the drought emergency occurs, Water Administration Department of Shandong Government and Yellow River Bureau in Shandong Province should make emergent operation plans and forward these plans to Yellow River Water Conservancy Commission at the same time with the consent of Water Administrative Departments under State Council. The following emergency measures should be taken accordingly to the Yellow River Bureaus.

4.1.1 Organization guarantee measures

(1) Establish the leading group and office for the safe of drought emergency and enhance the co – ordinance and organization. The director of Yellow River Bureau in Shandong Province is appointed as this group leader. The office under this leading group is being set up and the regular meeting is held to discuss the water flows issue. The meeting will be held anytime if emergency pops up.

(2) A professional working group is set up under which there are hydrological prediction & inspection group, water flow regulation group, supervision group and broadcasting group.

Hydrological prediction & inspection group: it is consisted of the people from the flood – prevention office and Hydrology & Water Resources Bureau, taking in charge of hydrological section, water valves and water level in vulnerable spots. More observation will be paid in every two hours on hydrological section flow when necessary. Pay close eyes to water flowing and update the predication results timely . Meanwhile, report the water flow and runoff forecast timely to the leading group and office.

Water flow regulation group: it is consisted of the people from Water Dispatching Dept, taking care of collecting weather, rainfall, drought and soil moisture information, according to which we could make the plans of water allocation on monthly or decade – days basis, so as to give regulation instructions, acknowledge current water situation, diversion condition and reserves situation. The sluice gate remote – monitoring management system and water – diversion information management system should be made use of fully to supervise and control the sluice gate that achieved remote – monitoring auto – controlled. If meet the emergency, close the gate according the relevant regulations and increase water flow of the control section quickly. Take advantage of water – diversion information management system to analyze and calculate the water quantity of river – way evaporation and leakage.

Supervision group: it is consisted of the people from relevant departments and bureau, taking care of supervising if the instruction is completely implemented. If emergency occurs, supervision will be carried on the spot regarding to the water diversion.

Broadcasting group: it is consisted of the people from relevant offices, taking charge of important media propaganda on Yellow River Regulation and depletion prevention, publishing water allocation and depletion prevention information timely on relevant media.

4.1.2 Measures on supervision and inspection

If the drought is severe, the staff in each department should enhance supervision and water – use control, complying with the disciplines and following the instruction strictly. The supervising team should be assigned to observe the water intake, conducting the implementation and diversion in beach area all the time. Meanwhile, this is must be under close supervision via sluice gate remote – monitoring system. Supervision is carried on by three steps: daily supervision, overall supervision and reinforced supervision, adopting spot checking, patrol checking and garrison checking. When the Yellow River water is found out – of – the – way, the timely – checking is needed to be done to the near water intake; when the Yellow River faces severe situations continuously, the person specially assigned for the task is required to be at the water intake.

4.1.3 Propaganda measures

Various ways and channels should be utilized to broadcast the significance of Yellow River water allocation and no flow – break with an aim to make people living along the Yellow River acknowledge the hazard.

4.2 Disposal measures when control cross – section discharge decrease to early – warning discharge

4.2.1 Disposal measures for first kind of emergent incident

If meet the first kind of emergent incident, we should report to the staff on duty timely in written form; the staff on duty should report to the in – charging people in water allocation department in 20 minutes; then this in – charging people should report to the Yellow River Conservancy Commission Water allocation Bureau. Finally the following measures should be taken: reduce the water diversion flow of sluice gate urgently till the diversion inlet closed; enhance supervising measures and inspect the working status on the spot to ensure the instructions well – implemented; strengthen the hydrology testing and pay an eye to the water level of depletion section both upstream and downstream area closely, which is needed by reporting once every two hours. When necessary, ask the people from Shandong Yellow River Hydrology and Water Resources Bureau to inspect the early – warning flow of depletion section.

4.2.2 Disposal measures for second kind of emergent incident

When meet the second kind of emergent incident, the responsible person should report to the staff on duty in province within 20 minutes and put up forward with the written form within 40 minutes; After the on – duty staff gets it, he should report it to the in – charging person in water allocation department in 10 minutes; this in – charging person should give the measures to take and report it to the Water allocation Bureau of Yellow Rive Conservancy Commission and the branch supervisor in province. Thus the following measures should be taken: stop the water diverting for industry and agriculture use above early – warning section. When necessary, stop all the diverting. Furthermore, the supervision groups should be sent by municipal bureau to the spot to supervise the instruction implementation, diversion – controlling and stop the beach area diversion with force; Inspect the sluice gate water level in depletion section both upstream and downstream areas and report it in each hour; When necessary, ask the people from Shandong Yellow Rive Hydrology and Water Resources Bureau to inspect the early – warning flow of depletion section.

4.2.3 Disposal measures for third kind of emergent incident

When meet the third kind of emergent incident, the responsible person should eliminate the faults and report to on – duty staff in provincial water allocation bureau within 20 minutes then give the written form report within 40 minutes; After the on – duty person gets it, he should report it to the in – charging person in water allocation department within 10 minutes; this person is requested to give the solving methods in 15 minutes and report it to the Water allocation Bureau of Yellow River Conservancy Commission. Thus the following measures should be taken: when the people from relevant municipal bureau is eliminating mistakes and restoring the normal order, the supervising group should arrive at the spot at the same time to investigate and coordinate problems. Reduce the diverting water flow in some water inlets and stop diverting when necessary; when necessary, ask the people from Shandong Yellow River Hydrology and Water Resources Bureau to inspect the early – warning flow of depletion section.

5 Applications of emergent plan

Since this scenario has been made, the drought and 3 rd emergency haven't popped up so far. At 8 Am. on 13 March 2006, the flow of Lijin Station is 113 m^3/s, less than discharge 150 m^3/s that is designated by Yellow River Conservancy Commission (not early – warning flow). According to the analysis and forecasting, if the measures were not taken, the flow of Lijin Station would become less and less. Therefore, the emergency system must be started immediately. According to the relevant regulations and requirements in this scenario, the diversion of sluice gate from Luokou to Lijin must be limited and close the diversion sluice gate along Lijin area: Xiaokaihe, Bojili, Handun, Dayuzhang, Mawan, Gongjia, Shengli and Caodian. Meanwhile, the two working group should be assigned to go to upstream and downstream respectively to supervise the diversion on the spot and make the discharge flow restored to 150 m^3/s. Through this rehearsal, it is indicated that the measures in this scenario is applicable and efficient, which offers beneficial lessons to the future – happened accidents.

6 Conclusion

As there are many unforeseen and uncontrollable factors in the work of Yellow River water allocation, we have to make amendment and frequent adjustment according to the actual situations when we are operating, so as to implement it better.

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Water Right, Water Market and Water – saving Society

Water – saving Potential Analyses on Large – scale Gravity Irrigation Districts in the Yellow River

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Abstract: Irrigation districts are the major water consumer in the Yellow River, which has annually diverted about 90% of the total water consumption of the whole basin in average. Restricted by economical condition, facilities of irrigation districts and management method and so on, the irrigation water badly wastes and the water utilized coefficient is lower, generally under 0. 5, greatly exacerbating the conflict of water resource shortage. According to the current water using condition of the Yellow River irrigation districts, this paper has put forward the concept of "water saving potential" and the corresponding analyzing and calculating method, and then analyzed water saving potential of the large – scale gravity irrigation districts in the Yellow River.

Key words: water saving potential, irrigation scheduling, furrow and border rehabilitation, water transport system, Yellow River gravity irrigation districts

The large – scale gravity irrigation areas in the Yellow River mainstream is the main body of consuming the Yellow River water resources, currently with irrigated area of 54. 802 million mu, occupying 48.6% of the whole irrigated area of the basin. Among them, the gravity irrigation area takes 50. 294 million mu, occupies 91.8% of the total large – scale gravity irrigation area in the Yellow River mainstream, while lifting irrigation area is 4. 508 million mu, only accounts for 8.2%. Through statistics, the average volume of water abstracted by the mainstream irrigation area between 1999 and 2003 averages 18. 448 billion m^3 including 1. 641, 1 billion m^3 by gravity irrigation area, occupying 89.0% of the total abstraction volume and 2. 037 billion m^3 by lifting water area, accounting for 11.0%. Considering the undistinguishable gravity irrigation area on the Lower Yellow River, so it's took a whole body to analyze. The study area of this paper focuses on Ningmeng gravity irrigation area of the upper Yellow River and the gravity irrigation area of the Lower Yellow River.

1 Definition of water saving potential

So far, there's no any standard for the connotation of water – saving potential generally acknowledged at home and abroad, so there's also no uniform method to calculate the water – saving potential. It is believed that water – saving potential of irrigation area, under the condition of the predictable technical level and by a series of structural and non – structural technical measures, refers to the difference between anticipated water requirement for irrigating and the amount of irrigation water in design level year, in which the biggest amount of saving water available is called available water – saving potential or theoretical water – saving potential.

There are four procedures to have to pass through from water source to turning to output: ① water would be transported from water source to field by diversion projects such as channel, conduit etc; ② water from field would be transformed to soil water; ③ through absorbed by roots, soil water would be transformed to crop water, maintaining the normal physiological activity of the crops; and ④ through complex physiological process of the crops, water from crop water would be formed to economical output. All has the possibility in the above several conversions to cause the water loss, and appears the waste of irrigational water. Therefore, irrigation water saving must aim at the above four links, through the measures such as suitable technology, economy, policy and so on, reducing the water loss in the conversion process as far as possible, enhancing the benefits of one cubic meter water. For the Yellow River irrigation area, although all of the above four links has the water – saving potential, the most primary potential exist in the first and the second, namely, the water – saving potential of conveyance system and field system, that is the key point of this article.

2 Analytic method of water saving potential

2.1 The method of subentry

2.1.1 Conveyance system of water

According to several computational methods which uses at present and the characteristics, the correlated experimental results of irrigation area, on the foundation of canal synthetical method, a new calculated model on water – saving potential is proposed – the method of equivalent canal. The concrete process is: Firstly, generalize different grade of channels to the equivalent channel; Secondly, make use of experimental data of typical pilot area to analyze the water loss and water use efficiency in unit length of different bank channels; Thirdly, according to pilot area achievement, analyze and calculate unit length water use efficiency and channel water use efficiency of the equivalent channel; Fourthly, calculate canal water use efficiency of the equivalent channel; Finally, through the method of equivalent canal, amount of saved water in conveyance system will be figured out.

(1) Generalization of equivalent canal system. Equivalent channel refers to this rank channel being able to represent characteristics of this kind of conveyed water channel in the irrigation area, including equivalence both in length and discharge. The equivalent canal system is the aggregate of different ranks of equivalent channels in irrigation area. It is generalized into:

Equivalent length:
$$l'_i = \frac{\sum l_i}{n_i} \tag{1}$$

where l'_i is equivalent length of the i grade channels, km; l_i is length of the i grade channels, km; n_i is total number of the i grade channels.

Equivalent discharge:
$$Q'_i = \frac{W_y \times 10^4}{8.64 T_i n_i} \tag{2}$$

where, Q'_i is equivalent discharge of the i grade channels, m^3/s; W_y is total abstraction volume of canal head water, $10^8 m^3$; T_i is run time of the i grade channels in day.

(2) Ascertaining of equivalent channel water use efficiency. From channel seepage formula:

$$\frac{S_1}{S_2} = \frac{A_1 Q_1^{1-m_1}}{A_2 Q_2^{1-m_2}} \tag{3}$$

where, S_1 is equivalent channel loss, $m^3/(s \cdot km)$; Q_1 is discharge of equivalent channels, m^3/s; A_1, m_1 is soil parameters of irrigation area; S_2, Q_2, A_2, m_2 is seepage loss, discharge, soil parameters of channels in typical test area respectively.

Water use efficiency in unit length of equivalent channels:

$$\eta_{iu} = l'_i \sqrt{\frac{Q'_i - l'_i S_{fli}}{Q'_i}} \tag{4}$$

where, η_{iu} is Water use efficiency in unit length of the i grade channels; S_{fli} is Water loss in unit length of the i grade channels, $m^3/(s \cdot km)$.

Water use efficiency of equivalent channels:

$$\eta_i = \eta_{iu}^{l'_i} \tag{5}$$

where, η_i is Water use efficiency of the i grade channels.

(3) Calculation of water use efficiency of equivalent canal system:

$$\eta_d = \prod_{i=1}^{n} \eta_i \tag{6}$$

where, η_d is canal water use efficiency.

(4) Calculation of the amount of water saving in conveyance system. Substitute the present abstraction volume of water, present water use efficiency, water use efficiency of equivalent canal system into the following equation, then the amount of saving water of entire conveyance system in the irrigation area can be figured out.

$$W_s = W_{sb} - W_{sa} = W_{sb}(1 - \eta_b/\eta_a) \tag{7}$$

where, W_{sb} is abstraction volume of canal head water before lining, m^3; W_{sa} is abstraction volume of canal head water after lining, m^3; η_b is canal water use efficiency before lining; η_a is canal water use efficiency after lining.

2.1.2 Field system

(1) Furrow and border rehabilitation. The Furrow and border irrigation is the major field irrigation way, its water loss mostly takes place in evaporation of the wet soil and the water surface, water leakage and deep percolation, the last two are the principal cause of total water loss. The furrow irrigation in a large scale of the Yellow River gravity irrigation area, adding the loam and sandy loam delivered by the river flooding, result in serious leakage of water through soil.

The calculated formula of amount of saving water:

$$W_{fr} = W_{frb} - W_{fra} \tag{8}$$

in which,

$$W_{frb} = \frac{m \times A_{fr}}{\eta_{frb}} \tag{9}$$

$$W_{fra} = \frac{m \times A_{fr}}{\eta_{fra}} \tag{10}$$

where, W_{fr} is amount of water saving in field irrigation after the alterationof channel and farmland, m^3; W_{frb} is amount of water saving in field irrigation before the alteration of channel and farmland, m^3; W_{fra} is amount of irrigated water in field after the alteration of channel and farmland, m^3; m is synthetic irrigation quota, m^3/MU; A_{fr} is irrigated area after the alteration of channel and farmland, MU; η_{frb} is water efficiency in field before the alteration of channel and farmland; η_{fra} is water efficiency in field after the alteration of channel and farmland.

(2) Adoption of irrigation quota on water saving. The irrigation area uses the water – saving irrigation scheduling, reducing the crops irrigation quota, then reducing the volume of irrigational water, namely amount of saving water, the formulas is as follows:

$$W_{sr} = W_{tr} - W_{sr} \tag{11}$$

in which

$$W_{tr} = m_{tr} \times A_{sr} \tag{12}$$

$$W_{sr} = m_{sr} \times A_{sr} \tag{13}$$

where, W_{sr} is amount of water saving after adoption of irrigation quota on water saving, m^3; W_{tr} is amount of irrigated water before adoption of irrigation quota on water saving, m^3; W_{sr} is amount of irrigated water after adoption of irrigation quota on water saving, m^3; m_{tr} is synthetical irrigation quota before adoption of irrigation quota on water saving, m^3/MU; m_{sr} is synthetical irrigation quota after adoption of irrigation quota on water saving, m^3/MU; A_{sr} is irrigated area after adoption of irrigation quota on water saving, MU.

(3) Adjustment of planting configuration. Because of different crops water requirement, different crops planting configuration affects water requirement of irrigation area; the adjustment of planting configuration changes synthetical irrigation quota, the difference in water requirement is the amount of saving water. The formula is as follows:

$$W_{ad} = W_{adb} - W_{ada} \tag{14}$$

in which

$$W_{adb} = m_{adb} \times A_{ad} \tag{15}$$

$$W_{ada} = m_{ada} \times A_{ad} \tag{16}$$

where, W_{ad} is amount of water saving after Adjustment of planting configuration in irrigation area, m^3; W_{adb} is amount of irrigated water before Adjustment of planting configuration in irrigation area, m^3; W_{ada} is amount of irrigated water after Adjustment of planting configuration in irrigation area,

m^3; m_{adb} is synthetical irrigation quota before Adjustment of planting configuration in irrigation area, m^3/mu; m_{ada} is synthetical irrigation quota after Adjustment of planting configuration in irrigation area, m^3/mu; A_{ad} is irrigated area in irrigation area, mu.

(4) Combination of well and channel. Water – saving potential with combination of well and channel means the corresponding reduction of canal water, after being substituted for by well water for irrigation, then the canal water saved is water – saving potential. The formula is the following:

$$W_{cw} = \frac{W_w}{\eta_c} - W_w = W_w\left(\frac{1-\eta_c}{\eta_c}\right) \tag{17}$$

where, W_{cw} is amount of water saving through combination of well and channel, m^3; W_w is amount of well irrigation substituting for canal irrigation, m^3; η_c is canal water use efficiency in canal irrigation.

Combination of well and channel and keeping proper proportion between well irrigation and channel irrigation may realize the joint operation of local surface water, ground water and the river water, achieving the targets of water saving, reasonable adjustment of ground water burying depth and maintenance of well ecological environment. Because of the influences of the climate, the rainfall and underlying surface conditions, the different regions have to adopt different irrigation proportion by well and channel, according to the related research, the condign proportion in arid and semi – arid area shall be 0.15 ~ 0.25, and that in semiarid and semi – humid area be 0.46 ~ 0.65.

2.2 The integrity method

According to the thought of studying water – saving potential, making use of synthetical irrigation quota, effective irrigated area and water use efficiency for both prior to and after adoption of water saving technique, the irrigational water demand after the implementation was analyzed. The difference of the irrigation water requirements is the water – saving potential available. The formula is:

$$W_{ias} = W_{iac} - W_{iaa} \tag{18}$$

in which,

$$W_{iaa} = m_{iaa} \times A_{ia} \times 10^{-4}/\eta_{iaa} \tag{19}$$

where, W_{ias} is available potential of water saving in irrigation area, 10^8 m^3; W_{iac} is status water requirement of irrigation area, 10^8 m^3; W_{iaa} is irrigational water requirement after the implement of water saving technique in irrigation area, 10^8 m^3; m_{iaa} is synthetically net irrigation quota after the adoption of irrigation scheduling on water saving, m^3/mu; A_{ia} is effective irrigation area of the irrigation area, 10^4 mu; η_{iaa} is water efficiency of irrigation after the implement of water saving technique in irrigation area.

3 Analysis of water saving potential in irritation area

According to the present amount of water used, canal water use efficiency, planting configuration, water – saving irrigation quota in Ningmeng and lower Yellow River irrigation areas, making use of the aforesaid two methods of subentry and integrity, the water – saving potential was analyzed.

3.1 Basic data for use

Table 1 lists the status quo of canal and field system and the parameters that is after alteration. Adjustment of planting configuration: according to water – saving plan for the irrigation areas, under the condition of keeping present irrigated area and irrigation quota, the ratio of foodstuff/ economy/ woods and grass is changed from present 74: 16: 10 to 70: 17: 13 in Ningxia irrigation area, the ratio of agriculture, forests, grass changed from present 91: 3: 6 to 60: 20: 20 in Inner Mongolia, and the ratio of foodstuff/ economy in planting configuration of the lower Yellow River is from present 67:33 to 69:31. The present irrigation quota and its adjustment value from crop, water saving irrigation quota are in the Table 2.

Table 1 Water use efficiency of conveyance and field system in large irrigation area on the mainstream of the Yellow River

Province	Diversion	Canal water use efficiency		field water use efficiency	
		current	improved	current	improved
Ningxia	70.48	0.46	0.715	0.76	0.94
Inner Mongolia	57.80	0.38	0.657	0.80	0.94
Henan	17.19	0.51	0.81	0.83	0.90
Shandong	57.90	0.55	0.80	0.86	0.90
Total	145.57				

Table 2 Irrigation quota of status and water saving in large irrigation area on the mainstream of the Yellow River

Province	Irrigated area (10^4mu)	Irrigation quota (m^3/mu)		Water – saving quota (m^3/mu)
		current	adjusted	
Ningxia	533.40	321	290	272
Inner Mongolia	893.78	227	210	193
Henan	1,030.90	200	168	174
Shandong	2,828.63	170	109	156
Total	5,286.71			

3.2 Analytic result of water saving potential

According to basic parameters of Ningmeng and downstream Yellow River irrigation areas, the water – saving potential was figure out through the methods of subentry and integrity (Table 3).

From Table 3, we can see that the available water saving potential of the large – scale gravity irrigation areas in the Yellow River mainstream calculated by method of subentry accounts for 10.265 billion m^3, only leaving the error – 0.59% compared with the method on integrity, the analytical result is quite reliable. The water – saving potential available of the Yellow River irrigation areas of Ningxia, Inner Mongolia, Henan and Shandong occupy 34.65%, 29.33%, 11.28% and 24.73% of the total respectively. The water – saving potential available in the Ningmeng irrigation area upstream is bigger than the Yellow River downstream, occupying 63.98% of the total. For the water saving potential of conveyance system and the field system, the first accounts for 64.40%, and the second accounts for 35.60%, the conveyance system is bigger than the field system in water – saving potential; because of influences of irrigational engineering, technical level etc. in these provinces, between various provincial capital areas Yellow River irrigated area conveyance system and field system water – saving potential exist difference.

Table 3 Result of water saving potential in large irrigation area on the mainst ream of the Yellow River

Prov	Item	Conveyance System	Field system					Total	method	Error (%)
		Canal lining	Plant adjustment	Water saving system	Furrow altera-tion	Well and Canal	Subtotal			
Ningxia	Avlwtsvpot ($10^8 m^3$)	24.9	3.16	1.83	4.71	0.97	10.67	35.57	34.18	-4.07
	Occupy the total (%)	72.85	9.25	5.35	13.78	2.84	31.22	100.00		
InnMgl	Avlwtsvpot ($10^8 m^3$)	20.25	2.55	2.88	3.46	0.97	9.86	30.11	30.52	1.34
	Occupy the total (%)	67.26	8.48	9.57	11.49	3.21	32.75	100.00		
Henan	Avlwtsvpot ($10^8 m^3$)	5.8	0.73	3.51	1.54	0	5.78	11.58	11.63	0.43
	Occupy the total (%)	50.09	6.30	30.31	13.30	0.00	49.91	100.00		
Shandong	Avlwtsvpot ($10^8 m^3$)	15.16	2.44	5.28	2.41	0.09	10.23	25.39	25.72	1.28
	Occupy the total (%)	59.71	9.61	20.8	9.49	0.35	40.29	100.00		
Total	Avlwtsvpot ($10^8 m^3$)	66.11	8.88	13.5	12.12	2.03	36.54	102.65	102.05	-0.59
	Occupy the total (%)	64.40	8.65	13.15	11.81	1.98	35.60	100.00		

4 Main conclusions

(1) This article through the analysis of connotation on water - saving potential, put forward the new concept of water - saving potential. It analyzed the water loss that are produced from the above four links and proposed that the analytic focuses of water - saving potential were the conveyance system and the field system. In view of the characteristics of the two systems, it proposed two water - saving potential computational methods, i. e. the method of subentry and the method on integrity. In the method of subentry, it proposed one new computational method of conveyance system water - saving potential - the method of equivalent canal; in field system, it mainly analyzed water - saving irrigation scheduling, adjustment of planting configuration, combination of well and channel, furrow and border rehabilitation etc. and gave the corresponding formulas. The available water - saving potential was calculated separately by the two methods and the calculation results were compared against each other, showing their basic tally.

(2) From the above analyses, we can see that there are tremendous water - saving potential in the Yellow River mainstream gravity irrigation area. If the suitable water - saving measures are adopted, the water use efficiency would be enhanced obviously in the irrigation area, the water loss in agricultural irrigation would be reduced, and the water resources would be saved greatly. That can abate the sharp contradiction of water shortage in Yellow River basin to a certain extent.

(3) The alteration of irrigation area should give priority to canal seepage control, with attention to balanced development. It can be seen among these technical measures for water - saving

potential, the canal lining is the most effective one for it occupies 72% of the total in Ningmeng irrigation area, and 59% of the total in the downstream irrigation area. Therefore, the emphasis of water – saving alteration should be put on the conveyance system. Through lining for conveyance system of the irrigation area, the amount of saving water is enhanced greatly. Because there are still 30% ~40% of water – saving potential in field system, its alteration should not be neglected and an attention should be paid to balanced development. Through the adoptions of water – saving irrigation scheduling, adjustment of planting configuration and furrow and border rehabilitation, the irrigation quota can be reduced, water use efficiency in field be heighten so that the efficiency of field water can be maximized adequately. The choice of water – saving measures should accord to the investment, benefit analysis in terms of the principles of few invests, swift effect and obvious output.

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Water Saving Methodologies: Leakage Control in Municipal Distribution Networks

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Abstract: The disparity between water demand and availability in the 3 – H river basins makes water saving a priority for the socio – economic and environmental needs of the area. In this context leakage control of municipal water distribution networks offers an excellent opportunity for promoting water conservation and enhancing the performance of the organisations providing water services. In fact urban distribution systems can lose more than half of the water put into supply, and this waste of resource not only entails an environmental damage, but also increases the costs of water production, as more chemicals and energy are needed to treat and transport water through the networks. This paper focuses on the advantages of active leakage control in municipal distribution systems both from the economic and environmental standpoints. An overview of the international best practice is illustrated and emphasis is placed on the approach to attain the economic level of leakage, showing how a proactive leakage policy, that places the network under flow and pressure control, has a short payback period and brings added value in terms of water conservation and improved financial and operational performance of the water utilities.

Key words: water, saving, leakage, economic

1 Introduction

Population growth and economic development in China over the last three decades have placed significant stress on water resources, and this is particularly acute in the 3 – H river basins. This area has per capita supplies of about 6 percent the world average (500 m^3 per capita, compared to the world's 8,335 m^3 per capita) and 22 percent of the national per capita supplies (2,282 m^3 per capita). Notwithstanding the resource scarcity, the region holds 35% of the national population, one third leaving in cities and metropolises such as Beijing and Tianjin, and it shows outstanding economic and agricultural performances, delivering one third of the national GDP and having 39% of the nation's agricultural land. In order to maintain its current growth, the region is exploiting water resources beyond sustainable limits (67%, 59% and 90% in the Yellow, Huai and Hai river basins respectively), but water – related problems such as water shortages, pollution, falling groundwater tables and flood/drought damages are becoming more frequent and severe. These problems have developed due to a combination of fast economic growth, natural geo – morphological, climatic and social circumstances and government population policies (1). The Ministry of Water Resources is dealing with the region's water availability issue so that it can keep its prosperity, and the South to North Water Diversion Project makes part of the strategy to supplement water resources to the area.

The studies on future water demand of the 3 – H basins envisage that the economic growth and restructuring and market forces will play a greater role in allocation, and these will lead to increased water use by industry in China. Urban and rural water consumptions are also set to increase with higher incomes. All the trends indicate an increase in water demand at least up to 2030 ~ 2040 after which there is some levelling – off to constant demand. This is consistent with experience in most other countries in the developing world.

Improved efficiency of water use from higher technology manufacturing processes and better performance of distribution networks are a must to balance the increasing demand without impairing the environment. This principle applies worldwide, particularly to areas with resource shortage. The reduction of non – revenue water in municipal networks is an issue that water managers around the world have grappled with for many decades in response to requests from environmentalists and regulators who consider the current levels of water losses in many countries are unacceptable.

The cause of high water losses in distribution networks are old aged networks undergoing poor (or non existent) maintenance and operation practices, but also the fact that the users are not paying the real cost for potable water, which puts less pressure on the need to enhance systems' performance. In dry places such as Israel, the cost of producing (including desalination), storing and conveying one cubic meter can easily be above \$ 0.8, but municipalities pay a much lower price than that to the National Water Company in order to make some profit when selling water to customers.

As soon as water utilities decide to put in place a leakage management policy, they face the dilemma of how far they must go in adopting measures against leakage since leakage control entails investment and changes in their usual operation practices. Water companies will seek to achieve the so – called "Economic Level of Leakage" (ELL) which will balance the costs of leakage reduction with the benefits that accrue. International experience has shown how leakage control operations – based on identifying and repairing the leaks in the network as well as reducing the pressure – will result in increased water availability, reduction of bursts and consequent savings in network maintenance and the extension of the operational life of the system.

The present paper describes the experience gained by the authors in the application of Active Leakage Control (ALC) in many networks in Italy and abroad. It shows the advantages of "sectorising" the network into District Metered Areas (DMA), i.e. bounded areas where inflows, outflows and main pressures are kept under monitoring in order to promptly identify increase in leakage levels. The "value for money" of this activity has been widely demonstrated, as it has payback periods of a few years. The benefits are significant, especially in places where the supply – demand balance is compromised due to resource shortage. Recovery of the current leaked water means less water serves to satisfy demand, as the availability of resource is increased (helping to postpone investments for supplementing resource) and costs of water production are reduced (less water is pumped and treated). Through the illustration of the ALC methodology, the authors wish to underline the importance for water companies to adopt the international best practice and adapt it to their specific context in order to work towards achieving their Economic Level of Leakage.

2 The economic level of leakage

The performance of water networks varies considerably around the world and, to a large extent, is closely dependent on the institutional and legal framework that each nation has in place for their water assets management. Whereas countries such as the UK, whose water sector has been privatised for a long time now, have a consolidated experience in leakage control, this is not the case in other nations, where leakage performance is hardly measured, and leakage control is based on reactive, and non proactive, measures. In the UK, water companies are requested every five years to present their corporate plans for the following 20 years, including an assessment of their assets and a financial model of forecast income and expenditure. Leakage targets are set by the regulator each year based on the companies' assessment of their Economic Level of Leakage, and most companies are operating at or close to their assessed ELL. But how is ELL estimated? And what actions affect the level of leakage?

2.1 Actions for leakage management

Prior to assessimg the ELL, it is necessary to understand which activities impact on the level of leakage in a distribution network. The following figure shows the 4 main actions for leakage management. By implementing or improving pressure management, active leakage control, the speed and quality of repairs and mains rehabilitation, the Current Annual Real Losses (CARL, represented as the outer box covering the blue, yellow and orange areas) will be reduced towards the economic level of leakage (Economic Annual Real Losses, EARL), shown as the next inner orange and yellow box bordered with a dashed line. The most inner box showed in yellow represents the Unavoidable Annual Real Losses volume (UARL) or the lowest possible level of leakage in a system at a very high cost though. Water managers must tackle the dilemma as to which combination of the four activities gives the EARL, and the answer is specific to each different system.

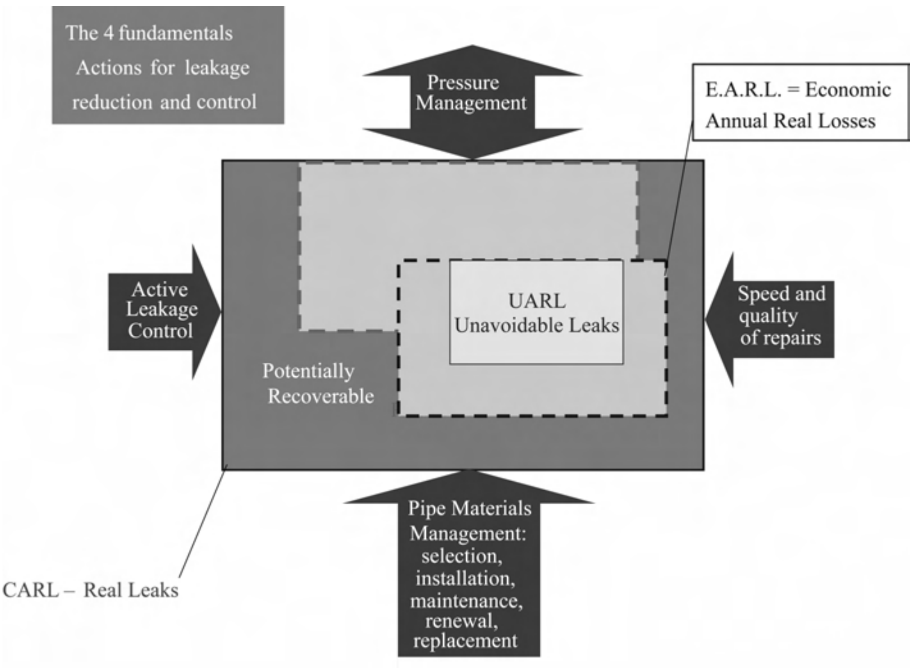

Fig. 1 The four main actions to reduce and control leakage (IWA)

The four actions for leakage management have two different time frames. Active leakage control and improving the speed and quality of repairs are feasible in the "short run" by changing the routine operating expenditure (OPEX), whereas pressure management and asset replacement and renewal entail long term investment (CAPEX). This report focuses on optimising the activities in the short term, i. e. ALC and repairs management, and discusses the processes that any water utility should go through for evaluating, reducing and optimising water losses, with the aim of getting closer to the ELL (or EARL, in the above figure).

2.2 Evaluation of economic level of leakage

In their path to enhancing leakage levels not all organisations can operate at their ELL and several factors may influence their leakage target such as economic, political, environmental supply sustainability short & long term, etc.

Though various techniques exist in establishing the economic level of leakage (ELL), assumptions may be made that:

(1) the cost of leaking water from a network is directly proportional to the volume of water lost;

(2) the cost of leakage control increases as the level of leakage decreases, and the rate of

increased cost becomes gradually steeper until a level is reached below which leakage cannot be further reduced. This is known as the "policy minimum" or base level of leakage.

When putting in place an ALC policy several costs must be incurred for monitoring flows and pressures (e. g. costs of instruments, construction of chambers, meters and loggers maintenance), pinpointing and repairing leaks. The following figure shows the costs against leakage for the various ALC operations, and the cost of water as leakage increases. Finally the total ALC costs and Total Costs curves are calculated adding up all the cost components.

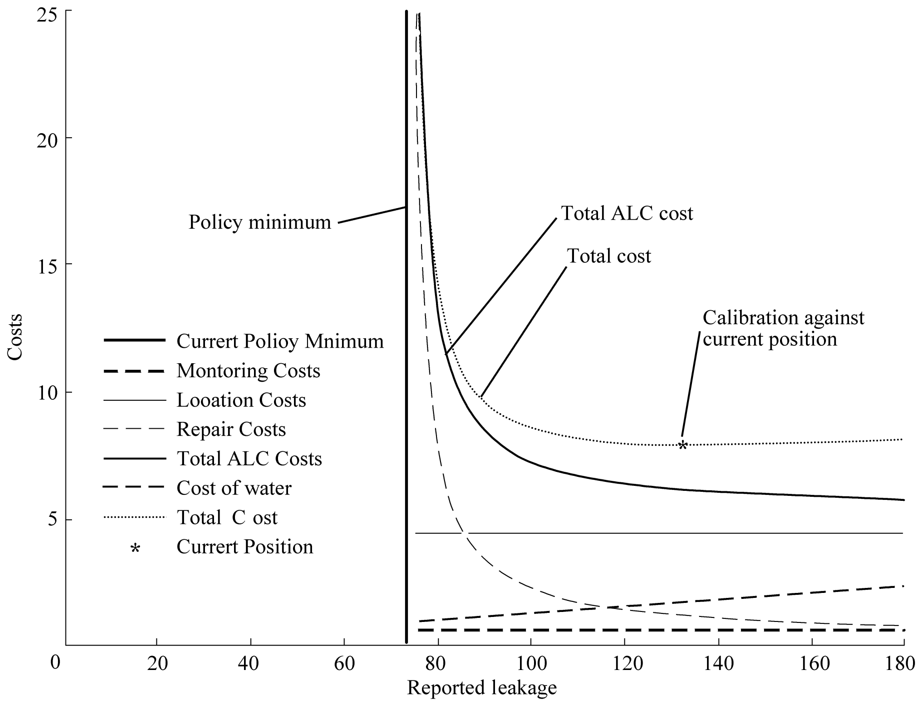

Fig. 2 Calculation of Total costs and ALC costs curves using the econometric model APLE

The following figure gives a simplified representation of the curves shown in the previous figure, just plotting the ALC cost curve (black) and the water cost curve (green). By adding them, the total cost curve (red) can be calculated and its minimum point corresponds to the ELL. Therefore "the ELL is the point at which the marginal cost of active leakage control, equals on average, the cost of leaking water".

Water utilities committed to improving their leakage management will target to reduce their Current annual real losses (CARL) towards the ELL or optimal position shown in the following figures. In achieving this task there are a number of econometric tools in the market that help to calculate the right balance for ALC intervention. In this context the writers have developed the DMS tool under the European Commission funded project TILDE, which by providing a set of costing data, establishes the ELL for ALC for a specific distribution system.

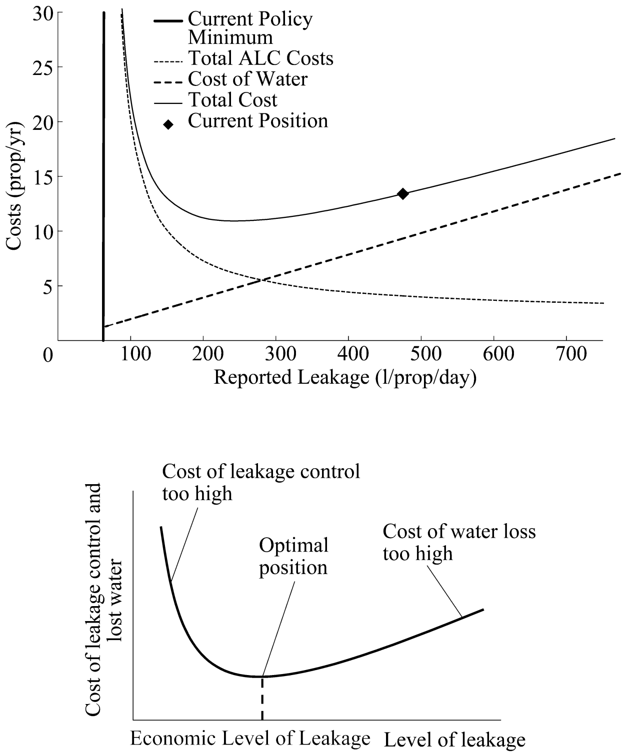

Fig. 3 Representation of the ALC and total cost curves to calculate the ELL or optimal position

3 Assessment of leakage performance

Prior to setting the strategy for managing leakage, any water company must ask itself how it is performing regarding leakage. Does it understand how much water is lost from its network, and how are losses assessed or measured? Furthermore, does it understand the components of water losses? Non – Revenue Water is the difference between water put into supply and water billed to customers but, how does Non Revenue Water (NRW) split up in components? In fact not all NRW corresponds to physical loss or leakage, but there is a portion of NRW which is authorized non billed consumption (e. g. water used for flushing pipes, streets cleaning, etc.). Additionally there are some administrative or commercial losses due to inaccuracies in billed consumptions (because meters may be underestimating) or caused by illegal connections.

The International Water Association (IWA) has defined a standard "water balance" that is recognized as the international best practice; it uses a common international terminology and consents comparisons of performance among countries. The process of calculating the water balance is a good initial step in any network diagnosis since it helps to evaluate the NRW's components and highlights aspects of the water utility that may need to be reinforced, such as for example the policy of meters replacement.

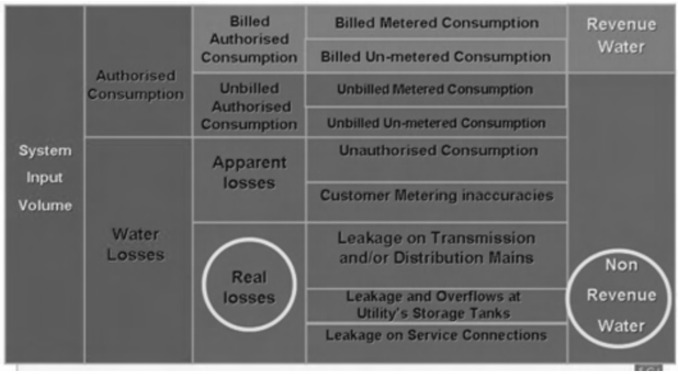

Fig. 4 Standard IWA Water Balance

The IWA standard water balance is gaining acceptance and has been adopted by a number of national organizations and utilities around the world. The writers have promoted its use through the development of a product within their TILDE project called "Leakage Check – Up" that consents any water engineer to benchmark the utility's performance through the calculation of IWA's simplified water balance and performance indicators. The tool starts by making the water balance described in the previous page and then goes ahead to elaborating the IWA international performance indicators for leakage, i. e. real losses/km/day, real losses/connection/day and the Infrastructure Leakage Index (ILI), i. e. the ratio of the current annual real losses (CARL) to the unavoidable annual real losses (UARL). The ILI measures how effectively active leakage control, repair management and asset rehabilitation are being managed at the current operating pressure. Any reader interested in testing this tool is advised to visit the TILDE project's water portal www. waterportal. com, where the Leakage Check Up can be used for free.

4 Active leakage control

Leakage management strategies can be classified into three groups: passive control, regular survey (sounding); active leakage monitoring and control in zones or sectors.

Passive control is where the water undertaking only reacts to leakage incidents that are apparent from visible bursts or drops in pressure, and which are usually reported by customers or noted by the company's staff. The method can be justified in areas with plentiful or low – cost supplies, and is often practised where water management is not highly developed.

Active Leakage monitoring and control (*ALC*) refers to monitoring the flows into zones or districts in order to measure leakage and prioritise leak detection activities. This is accepted as current best practice, being the most cost – effective strategy for leakage control.

The writers have developed a sound expertise in the application of ALC techniques through the development of many projects both in Italy and abroad (Athens, Tirana, Jordan, the Italian regions of Puglia and Umbria) (The economic viability of the methodology has been widely demonstrated as the payback periods have been very few years. The implementation of these projects consent the water utility to gain a better grasp of the network's operation and focalise on its critical areas or bottlenecks. For example the analysis of bursts and leaks in the network normally shows how a large percentage of problems are located in a limited part of the network. The figure below shows this concept for a project in which 90% of leaks and bursts were located in less than half of the network. The graph plots the cumulative leakage percentage in the y – axis against the all the DMA's of the network in the x – axis. The x – axis has the number of DMA, starting form the most critical (DMA 1) to the DMA with the least amount of leakage (DMA8). It can be seen how 90% of leakage in the first 15 DMAs, whereas the remaining 10% is found in the other 15 DMAs. This analysis proves extremely useful in targeting investments for leakage control, and is result of placing the network under an adequate flow and pressure monitoring.

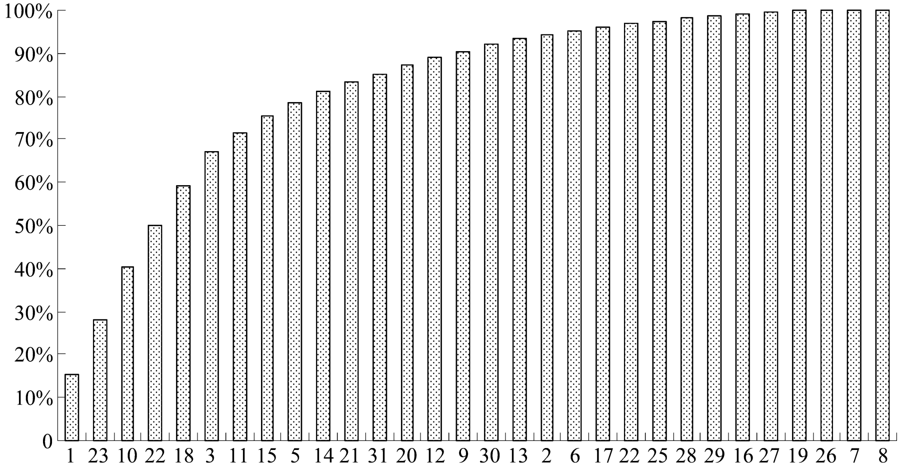

Fig. 5 Cumulative Leakage for the various DMAs in study site

The writers wish to emphasise the need to sustain the ALC system once the leakage control project is finalised in order to maintain or even improve the achieved leakage levels. This entails training of the organisation to make sure their assimilation of methodologies and technologies and the assignment of resources to manage and maintain the leakage control activity.

The two major aspects to learn about Active Leakage Control concern the methodology and the technologies used, which are explained in more detail in the following sections.

4.1 ALC methodology

The principle behind Active Leakage Control hinges on subdividing a large inter – connected water network into smaller, more manageable areas placed under flow and pressure metering. The writers have developed a methodology termed HydroZoom?, by which the network of a city is divided first into hydraulically independent areas that, on a second stage, are split into zones, which flows can be monitored permanently. These zones can be divided further into smaller areas, which can either be permanently or temporarily monitored districts depending on practical requirements. The methodology is illustrated in the following figure.

Flow is measured with permanent or temporary ultrasonic, magnetic, or mechanic meters . Additionally to flow, pressure is also measured within the zones. In this way operators can monitor and analyse pressure and flow data, particularly minimum night flows as they have a higher sensitivity for indicating if the consumptions has increased for no obvious reason, with the probability that this is caused by leakage or a burst.

The construction and use of a mathematical model of the network can prove extremely useful in simulating the operation of the network following the subdivision into DMAs and identify possible operational problems.

Once the zones have been implemented and the instruments installed, a detailed investigation of the water budget of each zone will be undertaken to identify the critical zones. The leakage level in each zone will be determined by implementing the minimum night flow method that will measure the minimum night flow into each zone and compare it with the legitimate night consumption which is calculated on the basis of the average consumption from the billing data and the typical demand profile for the type of consumer Leakage corresponds to the difference between the measured night

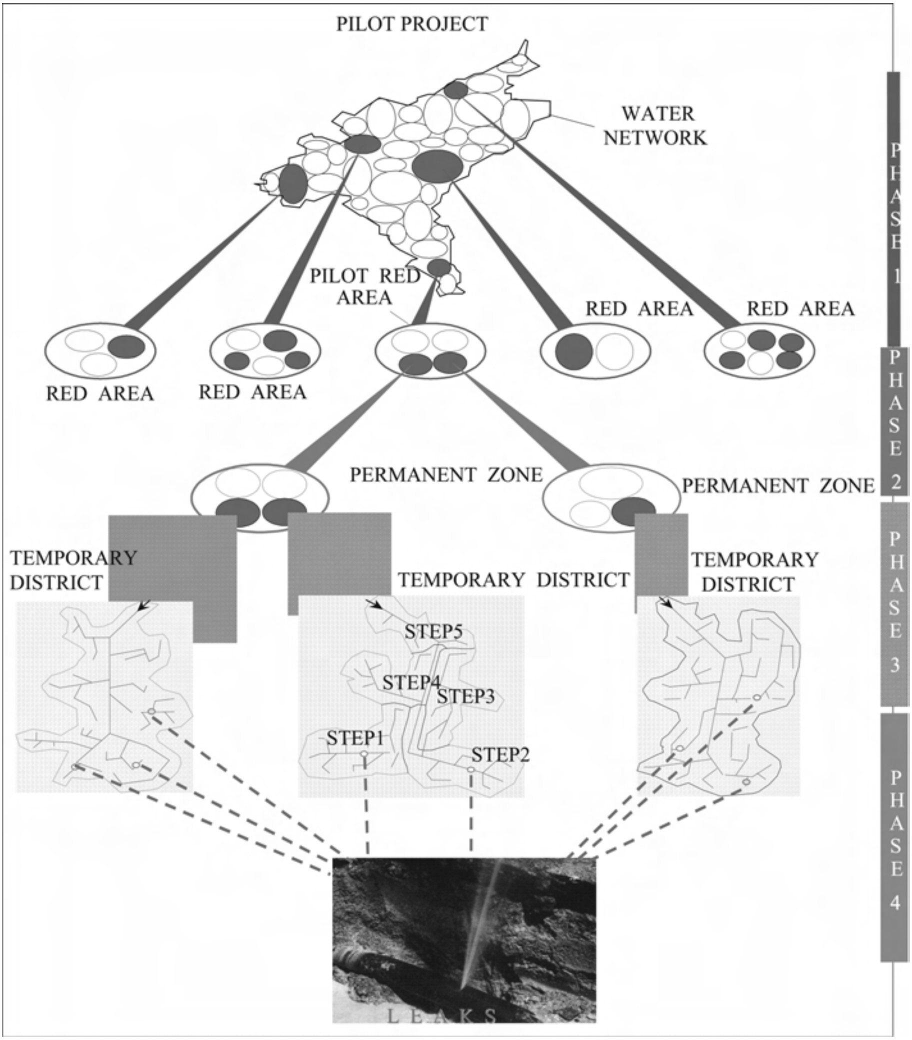

Fig. 6 Subadivision of the network into DMAs

flow and legitimate night consumption. This concept is illustrated in the figure below that shows the flow measurements in a DMA for a couple of days. The minimum flow is split into two components, the "legitimate night consumption", in yellow, and the calculated "leakage" in red. Those DMAs where leakage is higher will be considered as "critical" and will be permanently monitored.

The HydroZoom© approach represents the most cost – effective way of achieving an active control of a water network because it allows the whole network to be monitored, but to varying degree of detail depending on need and the risk of problems. It is a versatile and flexible technology which allows the intensity of control to be varied in time. For example, districts which might be considered critical because of their susceptibility to leakage might in time become low risk due to the substitution of certain mains or a change in pressure.

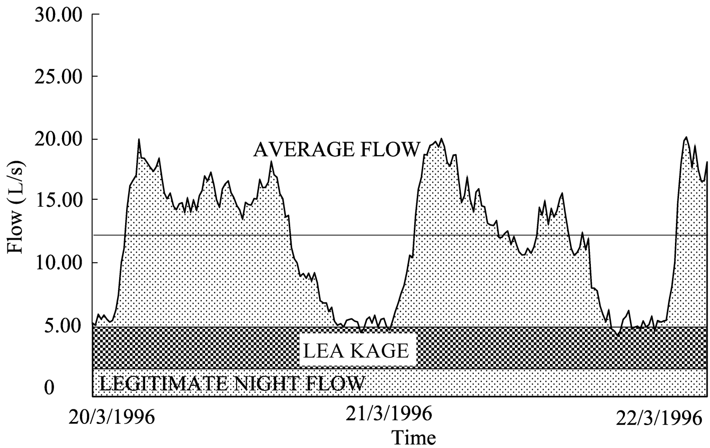

Fig. 7 Graph illustrating the analysis of the minimum night flow to determine leakage levels

4.2 Technologies for leakage control

Many technologies are involved in ALC activities, ranging from flow and pressure monitors to noise loggers and correlators that are used to detect and pinpoint leakage.

Correlators are the most widely employed instruments for leak detection. Their operational principle is based on detecting the noise that a leak generates in a pressurised system. The correlator uses two noise sensors, each located at either side of the suspected leak position. The leak sound arrives first at the most nearby sensor and there will be a "time delay", TD, before the sound arrives to the further sensor. The time delay, combined with the distance D between the sensors and the velocity V of the sound in the pipe, allows calculating the leak position.

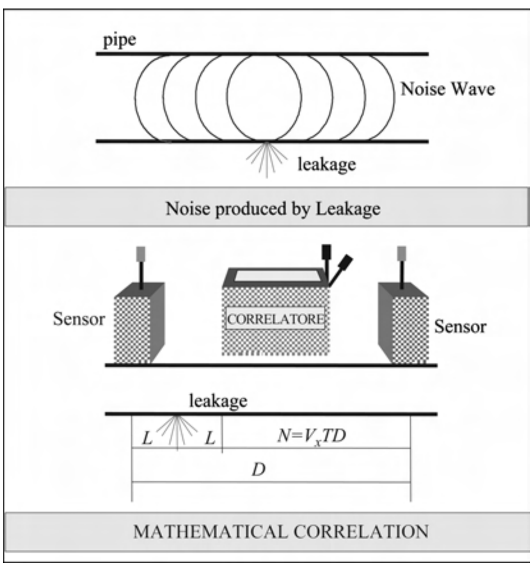

Fig. 8 Use of the correlator

The latest technological developments in leakage detection include the installation of "noise loggers" and "automatic correlators". The deployment of these instruments prevents the need of creating districts, which in complicated and hardly known networks are extremely difficult and costly to create.

Noise loggers are easily installed on pipe fittings at strategic points of the critical zone(s). The subdivision of the critical zone(s) into districts is no longer required, since these loggers are scattered all over the zone and monitor the generation of noise generated by leaks continuously. They are equipped with transmitters that start sending radio signals as soon as they detect the noise (LEAK mode). Radio signals are detected by a Leakage Patrol installed in a van that periodically drives into the zones or can be transmitted via GSM network to the remote computer. The Leakage Patrol identifies the location of the loggers in "LEAK mode" and leak locations can be investigated during, or at the end of, the patrol using correlators.

The most advanced instrumentation for leak detection are the "automatic correlators". These are a further evolution of the permanent noise loggers since they are capable of automatic localization and pinpointing of the leaks. These sensors are equipped both with a combined transmitter and a receiver, providing interactive communication between the deployed unit and operator. Noise loggers can also be integrated with GPS and GIS for automatic input leakage data into the operator's database. The noise loggers have the advantage of not needing of district creation since they can be scattered at strategic points of the zone.

In addition they substantially reduce the man – labour as they are capable of warning the operator on the presence and exact location of leak, thus avoiding all the painstaking operations of field correlations.

Noise loggers can be easily located at valves cup and any metallic fittings by means of a magnet fitted on the base.

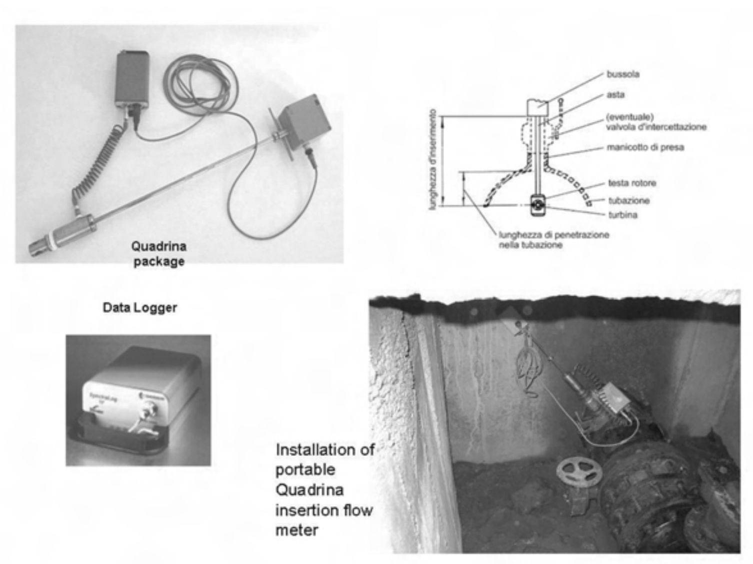

Fig. 9　Flow meters. Installation of portable quadrina

The choice of the technology for leak detection, be it classical district metering deploying conventional flow monitors, or more advanced instrumentation (noise loggers and automatic correlators), is decided upon the characteristics of the network and the operator's requirements. Once leaks have been located, operators' staff will be asked to repair losses in a prompt and efficient manner. In fact a successful outcome of the leak detection campaign depends significantly on the quality and speed in which repairs are made.

The measurement of water recovered will be conducted at the end of the leak repairs. Water recovered will correspond to the difference between the water that initially entered into critical DMA and the one that enters after the leak detection and repair campaign.

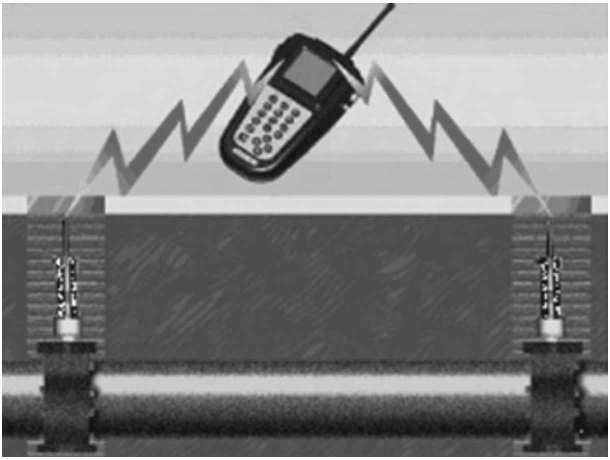

Fig. 10 Noise logger installed in teh network and transmission of signals to the Leakage Patroller

5 Conclusions

Reduction of water losses in municipal distribution networks is a great opportunity to optimise the use of such a precious resource and offers economic advantages to water undertakings which can improve their operational and financial performance through the set – up of a leakage management policy. In fact the level of leakage has become a main indicator of a utility's efficiency arena and water regulators in many countries, together with environmentalists, put pressure on water operators to reduce water losses.

The worldwide experience developed in the last decades has produced a set of best practice methodologies and powerful technologies including flow and pressure monitoring devices, leakage detection instruments and mathematical models for optimising network operation. The set up of a leakage management strategy that integrates all the best practice and adapts it to the specific features of each network consents to reduce water losses and define target levels for the water utilities. In this sense the aim that each water company should pursue is the attainment of the Economic Level of Leakage (ELL), which is defined as "the level of water losses which results from a leakage management strategy under which the marginal cost of the actions conducted for managing losses can be shown equal to the marginal value of water".

The leakage management activities that combine to achieve the ELL include an optimised pressure management strategy that allows to reduce the rate of bursts, thus saving investments in network maintenance and extending the operational life of the system; an optimised investment in mains and services renewals to ensure the compliance with regulatory factors; an optimised repairs policy to minimize leakage run time by improving leakage detection, location and repairing processes, improving repairs' quality and developing a leakage data – base; an economic activity of Active Leakage Control focused on improving the awareness, location and repair of unreported losses.

This paper has described the methodology developed by the writers for Active Leakage Control through the application in many projects in Italy and abroad. Termed HydroZoom?, the methodology is based on the sectorisation of the network into areas, which size depends on the level of detail required for the analysis of the leakage level. In fact efforts are prioritised in the most critical areas, where leakage is higher. The methodology entails the use of advanced technologies to monitor the flows and pressures within the district metered areas and the deployment of correlators and noise loggers to pinpoint leaks. A full overview of the best practice and technologies available for leakage control can be found in the Water Portal, www. waterportal. com, developed by the writers under the TILDE project that was funded by the European Commission under the 5th Framework Programme.

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Inspirations for China on Eco - environmental Water Requirement —From the Legislation in Australia and South Africa

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Abstract: Ensuring the eco - environmental water use is an important prerequisite for achieving sustainable development, and an essential foundation for constructing a harmony society between human beings and the nature. In Australian and South Africa, law and/or policy have been formulated to ensure the right of the environment for water, and/or to give a proper legal status to the environmental water needs. Analysing the law and policy in these jurisdictions and finding learns for China to learn are helpful for China to enhance its level of water resources management, and to strengthen the sustainable utilisation of water resources, and further to promote the achieving the harmony society in China.

Key words: eco - environmental water use, law and policy, Australia, France, South Africa

The continuing increase of water resources utilisation by human beings has been leading an increasing clear conflict between the water needs for economic development and those of eco - environment. On the one hand, the augment of water used for economic development has been leading reduced flow of rivers and ground aquifers, and further destruction of eco - environment. On the other hand, the discharging of sewage and waste industry - used water has been decreasing water quality, and further endangering the health of eco - environment. From a non - anthropocentric perspective, the eco - environment is entitled to proper water for its survival. This has been recoginsed in many of international legal and policy documents, although most of them in an implicit way. At national level, some countries have clearly acknowledged the environmental water right, although most of these countries have not employed the term of the environmental right to water but only have provisions on how to implement the measures to ensure the environmental water provision. According to the China's the 11 th Overall Planning Outlines, one of vital elements in constructing a harmony society is to promote the coordination among the economic development, natural resources and the environment. Without the eco - environment getting proper water, the harmony between the human beings and the nature has no foundation, and the strategy of sustainable development can not be achieved. In the paper, the law and policy concerning the eco - environmental water use will be discussed, and lessons from these countries can be employed to improve the mechanism of eco - environmental water use in China.

1 Australia

A lower and unevenly distributed precipitation, together with a high evaporation rates, results in a low recharge rates for surface water and groundwater by rainfall in Australia, and further makes Australia the driest inhabited continent in the world—thus representing a suitable case study with a severe water shortage. To tackle the issues relating to water resources, with the implementation of the Water Reform Framework 1994 and the subsequent Future Information on the National Water Initiative 2004, on the one hand, a mechanism for the transfer of the right to take water has developed in Australia; whilst on the other, protection for hydro - ecology has been strengthened there. However, under the federal system of government in Australia, the six States and the two Territories have the primary responsibility for natural resources management. For the purpose of this study, one particular state or territory should be selected. South Australia is selected, specifically because of its focus on the water right of water – dependent ecosystems.

In 1996, Agricultural and Resource Management Council of Australia and New Zealand (ARMCANZ), together with Australia and New Zealand Environmental and Conservation Council (ANZECC) formulated National Principles for the Provision of Water for Ecosystem. Those principles are designed to provide a kind of policy guidance, i. e., how to deal with the environmental water provision in making decisions on overall water allocations. According to this document, it is necessary to review the existing water allocation process, so as to reasonably allocate water for agriculture, household, industry and the environment. In order to ensure sufficient water being allocated for meeting the environmental requirement, twelve principles have been established. An new term, i. e., water – dependent ecosystem, is employed. Under this document, "water – dependent ecosystems are those parts of the environment, the species composition and natural ecological processes of which are determined by the permanent or temporary presence of flowing or standing water. The in – stream areas of rivers, riparian vegetation, springs, wetlands, floodplains and estuaries are all water dependent ecosystems". Regarding the term Environmental water requirements, it is defined as "descriptions of the water regimes needed to sustain the ecological values of aquatic ecosystems at a low level of risk. These descriptions are developed through the application of scientific methods and techniques or through the application of local knowledge based on many years of observation". The twelve principles declared in the documents read as follows,

PRINCIPLE 1 River regulation and/or consumptive use should be recognised as potentially impacting on ecological values.

PRINCIPLE 2 Provision of water for ecosystems should be on the basis of the best scientific information available on the water regimes necessary to sustain the ecological values of water dependent ecosystems.

PRINCIPLE 3 Environmental water provisions should be legally recognised.

PRINCIPLE 4 In systems where there are existing users, provision of water for ecosystems should go as far as possible to meet the water regime necessary to sustain the ecological values of aquatic ecosystems whilst recognising the existing rights of other water users.

PRINCIPLE 5 Where environmental water requirements cannot be met due to existing uses, action (including reallocation) should be taken to meet environmental needs.

PRINCIPLE 6 Further allocation of water for any use should only be on the basis that natural ecological processes and biodiversity are sustained (i. e., ecological values are sustained).

PRINCIPLE 7 Accountabilities in all aspects of management of environmental water provisions should be transparent and clearly defined.

PRINCIPLE 8 Environmental water provisions should be responsive to monitoring and improvements in understanding of environmental water requirements.

PRINCIPLE 9 All water uses should be managed in a manner which recognises ecological values.

PRINCIPLE 10 Appropriate demand management and water pricing strategies should be used to assist in sustaining ecological values of water resources.

PRINCIPLE 11 Strategic and applied research to improve understanding of environmental water requirements is essential.

PRINCIPLE 12 All relevant environmental, social and economic stakeholders will be involved in water allocation planning and decision – making on environmental water provisions.

Undoubtedly, all these principles are directly on eco – environmental water requirement, and deal with different aspects of the environmental water provision. In National Water Initiative 2004, eight inter – activating objectives of water resources management, outcome and the activities the every Government agrees to implement are discussed, and all of these involves the protection of environmental right to water, directly or indirectly. For example, the outcomes aspect requires providing legal foundation for surface water and groundwater environmental systems in the right to take water and the planning framework so that the water resources and water dependent ecosystems can be protected. Further, it requires recovering the over – allocated or over – abstracted surface water and groundwater systems and makes them reach a level of sustainability. In the aspect of water use for the environment and other public interests, ensuring the environmental water provision is emphasised. In monitoring and benchmarks, the environmental water use is an essential one.

In order to implement the Water Reform Framework 1994 and the National Water Initiative 2004, every State or territory has paid attention on employing legal method, and South Australia's Natural Resources Management Act 2004 could be taken as an example.

Firstly, the environmental right to water is recognised in this Act, that is to say, the environmental water requirement has got legal status. In Section 7(1), which provides the objects of the Act, it is provided that the water dependent ecosystems and relevant biological diversity shall be protected, and the legal water use rights of the water dependent ecosystems are recognised. Section 2 provides the basic elements of ecologically sustainable development, and determining environmental water provision shall be one of the vital parts. In Section 3, twelve principles that shall be followed in achieving ecologically sustainable development are established, and all these principles are concerned the environmental right to water directly or indirectly. It is obviously that the Act has adopted a comprehensive and ecologically sustainable way in managing natural resources, including water resources.

Secondly, the Act provides that, in fulfilling the environmental right to water, different management plan shall be employed. For example, ①it is required that the principles and policy to achieving the objects of the Act shall be formulated in the State Natural Resources Management Plan, however, the environmental right to water is recognised in the objects. ② It also provides that a water allocation plan developed by a regional natural resources management board must include evaluations on quality and quantity of water required by the water dependent ecosystem, and ensure the obtaining a reasonable balance among environmental, social and economic water needs.

Lastly, any individual or agency, or the public, has right as well as responsibility in the fulfillment of the environmental right to water. For instance, Section 170 provides that, "When making a decision under this Chapter that is based wholly or partly on an assessment of the quantity of water available or the period or periods during which water is available from a water resource, the Minister or other person or body making that decision must take into account the needs of the ecosystems that depend on that resource for water".

2 South Africa

In terms of water quantity, South Africa suffers a severe water shortage. Being located in a predominantly semi – arid part of the world, its climate ranges from desert and semi – desert in the west to sub – humid along the eastern coastal area. Its average annual rainfall has decreased by at least 10 percent in the past decade, with an annual rainfall in 1994 of 500 mm, falling to a 450 mm in 2001; both of these figures is only around 50 percent of the world average of 860 mm per year. Lacking any large or navigable rivers, the total flow of all the rivers combined amounted to about 53,500 million m^3 in 1994, but only about 49,000 million m^3 in 2004. At the same time, the rainfall is distributed quite unevenly, i. e., 65 % of the country gets less than 500 mm per year, and a further 21 percent of the country receives only 200 mm per year. Moreover, there is high average evaporation over most of the country, ranging from about 1,100 mm per year in the east to over 3,000 mm per year in the west. This situation increases when there is less rainfall. It is quite clear that the evaporation is well in excess of the annual rainfall, and therefore greatly reduces the surface runoff. "Owing to the variability and the high evaporation losses from dams, only about 62 % or 33,000 million m^3 of the average runoff can be utilised cost – effectively under the current technology". Regarding the groundwater, the geology of South Africa makes it difficult for groundwater to be used. On the one hand, most of the country is underpinned by hard rock formations, and only about 5,400 million m^3 of water may be obtained from underground resources per year; on the other hand, the groundwater is also saline for large areas of the country. According to the White Paper on a National Water Policy for South Africa (April 1997) issued by the Department of Water Affairs and Forest (DWAF), there was only just over 1,200 m^3 of available freshwater per capita per year for a population of 42 million. Data from the World Bank Group suggests that the water resource per capita was only 1,168.2 m^3 in 2000. The water law of South Africa emphasises the protection of the environment relating to water. As discussed in more detail below, this can be identified in law as well as in policy.

From the Constitution of the Republic of South Africa, one may find the origin of the environmental right to water. It provides that any development and utilisation of natural resources, undoubtedly including water resources, must be environmentally sustainable. In the Fundamental Principles and Objectives for a New Water Law in South Africa, of the 28 principles employed, at least nine are related to the environmental right to water, i.e., Principles 5, 6, 7, 9, 10, 13, 15, 16, and 17.

In Principle 5, the unity of the water cycle and the interdependence of its elements are recognised. Principle 6 states that, "[t]he variable, uneven and unpredictable distribution of water in the water cycle (in South Africa) should be acknowledged"; and Principle 7 describes the objective of the government in its management of water as being "to achieve optimum, long term, environmentally sustainable social and economic benefit for society from their use".

Further, Principle 9 emphasises the role of water to the environment, and reads as follows:

"The quantity, quality and reliability of water required to maintain the ecological functions on which humans depend shall be reserved so that the human use of water does not individually or cumulatively compromise the long term sustainability of aquatic and associated ecosystems."

Moreover, Principle 10 declares that, "[t]he water required to meet the basic human needs referred to in Principle 8 and the needs of the environment shall be identified as 'The Reserve' and shall enjoy priority of use by right. The use of water for all other purposes shall be subject to authorisation"; and Principle 13 set up the responsibility of the government to ensure and promote the realisation of the environmental right to water.

Principle 15 demands that, "[w]ater quality and quantity are interdependent and shall be managed in an integrated manner, which is consistent with broader environmental management approaches"; while Principle 16 provides that, "[w]ater quality management options shall include the use of economic incentives and penalties to reduce pollution; and the possibility of irretrievable environmental degradation as a result of pollution shall be prevented".

Principle 17 stipulates that, "[w]ater resource development and supply activities shall be managed in a manner which is consistent with the broader national approaches to environmental management".

In the White Paper on a National Water Policy for South Africa, the above principles are fully reflected, and there are many paragraphs relating to the environmental right to water. Firstly, the document states several key proposals that should be employed to guide water management in South Africa. Of these, two are of great importance to the environmental right to water. The first one is that all water in the water cycle "will be treated as part of the common resource and to the extent required to meet the broad objectives of water resource management, will be subject to common approaches"; and the second one is that, "[o]nly that water required to meet basic human need and maintain environment sustainability will be guaranteed as a right. This will be known as Reserve".

Secondly, Section 4.2, which is entitled "Optimum resource use and protection", explains the three important concepts, i.e., "optimum", "environmentally sustainable" and "social economic benefit", and states the interdependent relations between them. As to the meaning of the sustainable use of water resources, it is explained as, "even where the immediate demands for development are very high, society must find different development approaches which make sure that the use of water resources does not destroy the ability to recover".

Thirdly, the public trust obligations of the government and the priorities in water resources management are examined. In Section 5.1.2, in which public trust is discussed, the government states that it will carry out its public trust obligations in a way, which "makes sure that the requirements of the environment are met; takes into account the interconnected nature of the water cycle". In Section 5.2, the priorities are discussed in detail, and the environmental requirement for water is among the three types of priorities, i.e., basic human needs, environmental requirements, and international obligations. The document declares that, "[a]fter providing for the basic needs of citizens, the only other water that is provided as a right, is the Environmental Reserve – to protect the ecosystems that underpin our water resources, now and into the future".

Finally, the protection of water resources is discussed in detail in terms of three aspects, i.e., quality and its protection, resources protection, and source directed controls and their enforcement, in Section 6.3.

In the National Water Act 1998, there are some vital provisions that regulate the environmental right to water. The Preamble recognizes the sustainable use of water, the protection of the quality of water resources, and the integrated management of water resources. Further, the purposes of the Act include "promoting the efficient, sustainable and beneficial use of water in the pubic interest", "protecting aquatic and associated ecosystems and their biological diversity" and "reducing and preventing pollution and degradation of water resources".

As to the concrete provisions, the environmental right to water is regulated primarily in terms of three aspects, i.e., the Reserve system, the government's duty, power and responsibility, and the role of the public; these will be discussed in further detail below.

The first aspect is the Reserve system. In accordance with the National Water Act 1998, "Reserve" means the quantity and quality of water required to satisfy basic human needs, and "to protect aquatic ecosystem in order to secure ecologically sustainable development and use of the relevant water resource". In Chapter 4, the protection of water resources is regulated. In detail, the determination, preliminary determination, and effect of Reserve are stipulated.

The second aspect is the duty, power and responsibility of the government to protect the water related environment. The government is under a legal obligation to ensure that water is being protected, used, developed, conserved, managed and controlled in a sustainable manner, and the Minister of DWAF is ultimately responsible for promoting environmental values. Section 6 of the National Water Act 1998 provides that the national water resource strategy must "(a) set out the strategies, objectives, plans, guidelines and procedures of the Minister and institutional arrangements relating to the protection, use, development conservation, management and control of water resources within the framework of existing relevant government policy in order to achieve (i) the purpose of this Act; and … ; (b) provide for at least (i) the requirements of the Reserve and identify ,where appropriate, water resources from which particular requirements must be met". In accordance with section 45 (2), a proposed allocation schedule must reflect the quantity of water to be assigned to the Reserve. On reviewing a licence, of the three situations under which a responsible authority may amend any conditions of the licence, two relate to the environmental right to water, i.e., (a) it is necessary or desirable to prevent deterioration or further deterioration of the quality of the water resource, and (b) there is insufficient water in the water resource to accommodate all authorized water uses after allowing for the Reserve and international obligations. Section 67 provides that, in an urgent situation, or in cases of extreme urgency involving the protection of a water resource or the environment, the Minister of DWAF may adopt measures dispensing with certain requirements of the Act. According to the interpretation in the National Water Resources Strategy, "[t]o achieve sustainable use of water … by … striking a balance between water availability and legitimate water requirements, and by implementing measures to protect water resources" is one of the three fundamental objectives for managing South Africa's water resources. Moreover, a proportion of the available water is under the direct control of the Minister of DWAF, and the Reserve is given the highest priority, within which the provision of water for safeguarding and sustaining healthy ecosystems follows the first objective – ensuring basic human needs – to be met. Further, the National Water Resources Strategy (First Edition) discusses the protection of water resources in detail in Part 1 of Chapter 3.

The third aspect is the role of the public, including environmental interest groups, in protecting the environmental right to water under a proper legal procedure. Under the National Water Act 1998, the public is entitled to participate in environmental impact assessment procedures in accordance with the law. According to section 81, when the members of a governing board of a catchment management agency are appointed, the Minister of DWAF must balance the interests of water users, potential water users, local and provincial government and environmental interest groups. Moreover, in accordance with the National Environmental Management Act 1998, (a) any person or group of persons may in the interest of protecting the environment enforce environmental laws, and (b) any person may in the interest of the protection of the environment institute and conduct a private prosecution.

3 Inspirations for China

In Chinese law and policy concerning water resources, some provisions on eco – environmental water use can be found. For example, in Chapter One of China Water Law 2002, there are two articles that involving eco – environmental water use, i. e., Article 4 and Article 9. Article 4 requires that, in exploiting, utilising, saving or protecting water resources, as well as preventing or controlling of water disasters, livelihood, production and business, and the eco – environment water uses shall be coordinated. Article 9 provides that the State shall improve the eco – environment.

In Chapter Three, which is entitled "Exploitation and Utilisation of Water Resources", there are three articles. Article 21 provides that, "[i] the exploitation and/or utilisation of water resources, the water – use demands for the livelihood of urban and rural inhabitants shall be satisfied first, while the agricultural, industrial and eco – environment water – use demands, as well as navigation demands etc., shall also be taken into consideration. In the exploitation and/or utilisation of water resources in arid and/or semi – arid areas, eco – environment water – use demands shall be fully taken into consideration. Under Article 22, which is on inter – basin water transfer, when an inter – basin water diversion project is to be carried out, a comprehensive plan and scientific study must be undertaken, and an all – round consideration is to be given to water – use demands in the basin from which the water is to be diverted as well as in the basin into which the water is to be diverted, while damage to the eco – environment shall be prevented. Article 26 (2) reads that, "In the construction of hydropower stations, the eco – environment shall be protected, while the requirements for flood control, water supply, irrigation, navigation, bamboo and log rafting, fishery, etc. shall be taken into consideration".

Also one can find some provision concerning eco – environmental water use in the policy documents or rules issued by the Ministry of Water Resources, such as Several Opinions on Water Rights Transfer (January 11, 2005) and Construction Framework for Water Rights (January 11, 2005). However, is is obviously that no detailed or practical measures have been formulated in any Chinese law and policy to ensure the eco – environmental water requirement being met.

Although, "[a]t present, our society has not yet attained a level of sustainability whereby humanity honours and respects life upon this planet and uses fairly and equitably the resources it provides", we still must do our best to reach this level. Through comparison, there are the following inspirations that could be found from Australia as well as South Africa for China.

(1) Land ethics should be regarded as one of philosophies in water resources management. However, the ecosystem can not to claim its right to water by itself, an effective and efficient mechanism should be designed to fulfill the environmental right to water. Under the present Chinese water resources management framework, the government should take the main responsibility to ensuring the fulfillment of the environmental right to water.

(2) The holder of the environmental right to water should be classified. The eco – environment is too vague to be ensured for water being provided, and it is necessary to identify important sites as the holder of the right.

(3) Practical process and steps should be formulated for measures being taken to fulfill the environmental right to water. Without due process, the environmental right to water in a right in paper for ever.

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Id.
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Id., section 2.
Id., section 1(1) (xviii).
Id., sections 16 – 18.
Id., section 3.
Id., section 6 (1) (a) and (b).
Id., section 49 (2).
See DWAF, Supra note 10, p. 7.
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Catchment management agency is a kind of responsible authority other than the Minister of DWAF, and a catchment management agency exercises relevant power or duty assigned by the Minister in respect of water uses.
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Analysis and Calculation of Agricultural Risk Compensation in Water Right Transition

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Abstract: It analyzed main factors which might affect agricultural water amount under water right transferor. Based on damaged degree of diversion flow at different water coming frequency, influence of agricultural water use caused by water right transfer was analyzed and relationship between different water coming frequency and water deficit was established. Then calculated agricultural water deficit and cost of agricultural risk compensation. Calculation formulas of agricultural risk compensation were put forward through the above analysis and disunity problems on the cost was solved.
Key words: water right transition, risk compensation, cost

1 Situation of water right transition in Yellow River Basin

With commence of the development strategy of west China, many industry projects on coal are developed greatly in Ningxia and Inner Mongolian. The main of those projects need a lot of water resource. And this made water demand increase local development indubitably.

Water saving irrigation is the only way to resolve the problem of water shortage, the focus of water saving is in agriculture. The phenomena of wasteful irrigation water are serious in regions of Ningxia and Inner Mongolia, and those regions have a very high water saving potential. Water right and water market theory were put forward by YRCC to optimize water resource collocation. Through water right transition, the local industrial projects will gain the index of water diversion of Yellow River.

Water right transition is a new work in the Yellow River Basin without precedent. The whole work begins from experimental unit to a larger range. Five industrial projects were selected as experimental unit in Apr. 2003. And water saving irrigation districts is Nanan and Qingtongxia irrigation districts. From then on, work of experimental unit on water right transition was put into practice.

In the practice, water shortage was solved successfully in Ningxia and Inner Mongolian economic and social development. And industrial water consumption is supported by agricultural water saving irrigation and agriculture is returned by industry. It was given that a new model for water saving society building and accelerating harmony development of economy, society, resource and environment.

Water right transition in the Yellow River Basin were standardized by "Management and implementation method of water right transition in the Yellow River" (June, 2004. by YRCC) and "water saving engineering verification method of water right transition in the Yellow River" (Nov, 2005. by YRCC). In the criteria, water right transition system was built up; approval purview and program on water right transition were standardized. Besides, the compensation system was built and general plan on water right transition in Ningxia and Inner Mongolian was replied.

Successful practice of water right transition made a great role in sustainable development on local economy and society. It also resolved the problem that caused by water use conflict between agriculture and industry. Then the enterprise developing space was enlarged, water use efficiency and water use benefit was improved greatly.

2 Cost calculation in water right transition

Cost calculation is an important process in the work of water right transition, it bases on water price theory and market regular. This work is built on the mutual benefit principle. And it also considers the factors such as water resource condition, water right transition duration, cost of water conservancy projects and compensation of economics and ecology.

According to "Guidance advance about water right transition experimental unit work at the Yellow River in Inner Mongolian and Ningxia, issue by ministry of water resources", general cost of water right transition includes:

(1) Cost of water saving projects including channel system lining, water conservancy construction, gauging water device and additional cost on water saving;

(2) Cost on water saving engineering running. It means additional annual maintenance cost as mentioned above;

(3) Cost of water saving projects updating. It is an additional cost that happened when design life of water saving engineering is shorter than duration of water right transition;

(4) Risk compensation caused by different water suppliant assurance;

(5) Necessary compensation on economics and ecology and other expenditure.

3 Analysis and calculation in agricultural risk compensation

Method of agricultural risk compensation is not integrated at present in water right transition. So its standard should be uniform.

Water consumption in irrigation districts will decrease at dry years according to water resource schedule in the Yellow River. But rate of water suppliant assurance will higher than 95% to insure the industry production. In this cause, some field will not be irrigated for water shortage and field output will decrease. The result is that compensation should be given to farmers.

The procedure of compensation calculation is under the following: firstly, calculate agricultural mean annual water resource occupied by industry, secondly count the decreasing agricultural benefits caused by irrigation water shortage, it's the annual industrial risk compensation cost.

Plot of occupied water amount by industry can be seen at Fig. 1.

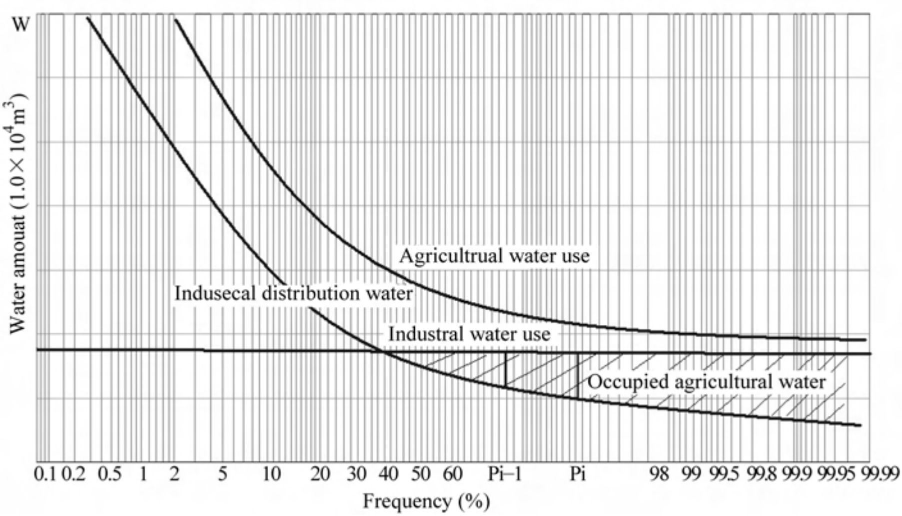

Fig. 1

The formulation can be seen at following:

$$\overline{W} = \frac{\sum (P_i - P_{i-1}) \times (W_i + W_{i-1})}{2} \tag{1}$$

where, $\overline{W}$ is agricultural mean annual water amount occupied by industry; $(P_i - P_{i-1})$ is difference value between adjacent frequency; $(W_i + W_{i-1})$ is the sum of losing agricultural water amount under adjacent frequency.

In dry area and water scarcity region, irrigation water suppliant assurance is between 50% and 75%, and the industrial is between 95% and 97%. Under different assurance rate, irrigation water amount and industrial water amount will be figured out. When it keeps the assurance of industry, the amount of agricultural water will decrease. To accumulate this decreasing amount, the mean annual water resource occupied by industry can be calculated.

Irrigated area will decrease in water right transition. This decreased benefit will be calculated based on different value of field income between irrigated and no-irrigated.

$$A_s = W_s / M_j \quad (2)$$

where, A_s is decreased irrigated area in irrigation districts; W_s is water amount that industry occupy from agriculture; M_j is irrigation quota after water saving implemented.

$$C_f = N_z \times A_s \times B_c \quad (3)$$

where, C_f is agricultural risk compensation in the duration of water right transition; N_z is years of water right transition; A_s is decreased irrigated area in irrigation districts; B_c is per. different value between irrigated and no – irrigated area

4 Conclusions

It is an important issue that how to avoid influence to agricultural irrigation in water right transition at dry year. This paper analyzed damaged degree in different water suppliant assurance rate. And it also gave correlativity between water suppliant assurance and losing water amount. Then agricultural risk composition method was list. But it was a rough estimation to agricultural risk composition, and the system is still imperfect. There are many factors that affecting the composition, so the further research should be done about the agricultural risk composition in water right transition.

On Formation, Defect and Innovation of the Existing Water Right Institution of the Yellow River

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Abstract: According to the theories of property right economics and institutional economics, this paper presents 3 – stage water institutional evolutions of Yellow River from informal constraint to formal constraint and the formation of tradable water right institution. It discusses the defects of the existing water right institutional arrangements such as incomplete definition of water rights, low water prices, difficult adjustment of water shortage and surplus. It also provides ideas and suggestions for the existing water rights institution innovations, for example, to construct controllable water resources projects, to raise water prices step by step, to improve relative laws for water affairs.
Key words: the Yellow River, water right institution, formation, defects, innovation

1 The formation of the existing water right system of the Yellow River

At the time when the People's Republic of China was founded, the water resource of the Yellow River was relatively abundant and few water laws and regulations were enacted. The water right system contained mainly informal constraints, such as the traditional custom on water utilization. Later, with the increase in population and the growth of the economy along the Yellow River, a conflict in the demand and supply of water resources has gradually emerged and has become increasingly serious. Particularly after 1970s, water drying – up has occurred as a direct result of industrial and agricultural development. With the increasing shortage of water resources and the value of water, a paradigm shift has occurred concerning the exploration and utilization of water resources along the Yellow River. Laws and regulations have been used to guide the exploration and utilization of water resources, instead of relying the traditional ways of water utilization. The water right system of the Yellow River has shifted from informal constrains to formal constraints. In recent years, tradable water right has even emerged.

1.1 The water rights system of Yellow River from 1949 to 1977

At this stage the water right belonged to the public, and was administered by the Yellow River Conservancy Commission (YRCC), which controlled the allocation of water resources along lower and upper streams, and the priority was given to industrial and agricultural development. A series of formal water right institutional arrangements were made for comprehensive harnessing, exploration, and utilization of water resources along the Yellow River to mitigate flooding and to generate profits. The Yellow River began to change from "China Crisis River" to a beneficial river.

However, if one takes a general view of the Yellow River's water right system in this period, it is easy to find that the water right system was still dominated by the informal constraints. The majority of the water was used for irrigational purpose, which was primarily governed by the unspoken historical rules of water rights and the traditional ways for water utilization. During this period, water supply was relatively abundant. Since simple soil canals were used as conduits for irrigation, water was easily lost through infiltration and drainage. Although the allocation of water usage was established, there was no measure to monitor and quantify the water consumption for the users of the Yellow River water. There was no institutional environment to change people's water awareness and water utilization habits. That is to say, the farmers still follow their old water awareness and water utilizing habits. Due to the abundance of water resource, only a small fraction of the water was controlled and utilized by the authorities. The majority of the water just flowed through the river. The water supply in the Yellow River was seemingly unlimited and inexhaustible. Water was considered as a free gift and used at will. Flooding irrigation was practiced along the Yellow River. Moreover, there were not any water charge and water resource fee in those days. No restrictions were applied to water consumption. There was no need to consider the efficiency of water utilization. Although the central government proposed to save water during agricultural irrigation, there was no real leverage to control the water consumption and usage. There lacked perfect policies to promote water saving. There was no incentive for the farmers to save water during irrigation. Because of the public ownership, the informal constraints dominated the water right system in this period.

1.2 The water right system from 1978 to 1986

After 1978 when the third Plenum Session of the 11th Central Committee of the Communist Party (CCP) was held, many formal constraints of the Yellow River Basin were established. The Yellow River Water Distribution Plan was implemented. Some provinces, such as Shanxi Province, even enacted the water utilization permit system. Water charges and water resource fees were put into place. These formal constraints strengthened the unified administration and the multi – level management of water resources, and have played a positive role in conserving water resources, improving water utilization efficiency and alleviating the drying – up of the Yellow River. However, the formal constraints can function well only when they are recognized by the society and compatible with the informal constraints. It was necessary to ease the tension between the formal and informal constraints, which affects the direction of economic activities. Despite the fact that the water was distributed for the individual province along the Yellow River Basin during this period, the water was uniformly distributed among farmers. Water was still considered as a public property. The water price was so low that the farmers did not feel any advantage for water saving. There was no system to trade unused water. Even if water was saved, the users did not really benefit from such efforts. So they lacked the enthusiasm to invest water – saving facilities. The efficiency of water allocation was naturally very low. In addition, the concept of flooding irrigation, which practiced for thousand years in China, was deeply rooted in people's minds, and it was difficult to change this traditional practice within a short timeframe. Such water awareness even hindered the implementation of the formal constraints. It was even difficult to collect water utilization fees in some districts, and the collection rate was only 40% in some of the downstream provinces. Even though formal constraints were established in this period, the informal constraints still played a dominant role.

1.3 The water right system from 1987 to present

Since 1987, the demand for water in the Yellow River basin was significantly increased as a result of growing population and rapid economic growth. The relationship among the users of the water resources became complex. The People's Republic of China Water Law, which was passed in 1988 and the subsequent amendment was made in 2002, regulated the behaviors of water utilization among all economic bodies all the Yellow River. In 1987 the State Council approved the Yellow River Water Distribution Plan, which marked a new era for water allocation in the Yellow River basin. In 1994 the first formal constraint for water drawing – The Yellow River water Drawing Permit Implementation Details was enacted. But the new rules strictly inhibited water trading and therefore prevented the formation of the water resource market mechanism. The collection of water resource fees was limited to Shanxi and Shaanxi Provinces and the Inner Mongolia Autonomous Region. The water price remained low. However, the transfer of water rights began to emerge in this period. The Yellow River Water Right Transfer Rules were established in 2004 and the Ministry of Water Resources published regulation for water right transfer in 2005, both allowed the transfer of water rights across China. Ningxia Autonomous Region and Inner Mongolia Autonomous Region even allowed cross – sector water utilization right transfer. The transfer of water rights increased the value of water, which was reflected through the transaction price. The transfer of water rights also provides an opportunity for people to have a quantitative and intuitive understanding of water shortage, and serve as guidance for a rational allocation and utilization of the water resource.

At this stage many formal constraints of the Yellow River were introduced. The water right system was shifted from the traditional informal constraints to formal constraints, which were represented by the Water Law and various rules and regulations. Water drawing was controlled by the permit system, and quantitative allocation of water across the entire Yellow River Basin was implemented. A new water right system in the basin and in each administrative region was formed. The new laws, rules, and regulations paved the ways for more efficient utilization, administration, and allocation of water resources, and thus have increased the value and profitability of water.

2 Defects of the existing water right system of the Yellow River

The existing water property right system of the Yellow River provides a platform for water allocation, management and protection. But generally it is a public water right institutional arrangement based on planned economy. Because in most rivers in China there is no distinction between public and private water, and with the effects of the traditional planned economy system, the government was so accustomed to allocate the water resources. Although the transfer of water rights has occurred in the Yellow River basin, the progress of the formation of the real water market remains slow. Even with increasing shortage of water in the Yellow River, the current water right system still prevents the more efficient use of water due to the following reasons.

2.1 The incomplete definition of the Water Rights

The existing water rights have not been completely defined. It is difficult to meet the demand for water transaction. Legally the ownership belongs to the government, which has the full authority for allocating and developing the water resources. The management of the water resources is administered by the Yellow River Conservancy Commission, a branch of the Ministry of Water Resources that controls the entire basin. The management of water flowing through each individual province and autonomous region is conducted by the local water authorities. In the market economy, the governing administrative authorities should be separated from the management entities. The Yellow River's water utilization rights are not completely defined. The Yellow River's water utilization rights were mainly reflected in the ability to allocate water resources. According to the Yellow River Water Distribution Plan which was approved in 1987, the amount of water that could be used by the individual province was clearly defined. But three defects still exist. Firstly, the initial water utilization rights are just defined in the municipal level. Those under this level such as the counties, the irrigation districts or the individual households have not been clearly defined yet. The water distribution inside each city remains in a soft constraint. Secondly, the water volume of branch stream has not been measured quantitatively in the current water distribution plan, and Surface water and groundwater has not been allocated harmoniously. Thirdly, the proper water utilization order and the guarantee ratio among the different industries of the national economy have not been clarified in the current water distribution plan. There exists a disproportional relationship between water consumption and water utilization efficiency. The larger users of water always demand for more water and waste more water, which leads to even more severe water shortage. Defining initial clear water rights and conducting water rights transfer have become urgent in the Yellow River basin.

2.2 Low price of water, duty defects of the water administrative authorities and inefficient water operations

Currently, the irrigational water price is still far below the costs of water supply. Since 2000, Ningxia Autonomous Region has increased the water price 3 times. But it is less than 40 percent of the costs of water supply. The water price along the Yellow River remains very low. It does not cover the costs of water supply, and does not reflect the opportunity cost of the utilization of the Yellow River water resources. The reason is that the water price is not determined by the costs of water supply. More importantly, the low water price can not reflect the Yellow River water scarcity and can not become leverage for more efficient use of water. It even stimulates the wastage of water resources. In addition, the low water price induces a heavy financial burden to the water administrative authorities. Under the market economy in China, the budget from the central government for the water administrative authorities has gradually decreased over the years. Their main source of funding comes from the water rates collection. This revenue is too low to pay for the costs of water operation and management. Many water projects are too old and need the necessary maintenance and renovation. But the water administrative authorities cannot afford the costs of maintenance and renovation, which lead to a reduced efficiency in water operation and management.

2.3 Difficulties in the adjustment of water surplus and deficiency and low water resource allocation efficiency

The Yellow River basin covers a vast area of the country. The natural conditions, precipitation, and irrigation methods are different in each province along the river, which directly affects the water demand. Some provinces may need less water than other. Therefore it is necessary and possible for the areas with surplus water to supply the other areas with water deficiency. Currently people have realized that it is difficult to rely on the traditional water distribution plans to adjust water supply in the Yellow River Basin. On August 1, 2006, The Yellow River Water Volume Adjustment Acts was implemented. However, a market mechanism must be established to encourage regions with water surplus to save water, and to sell the surplus water to those regions with water deficiency. This would benefit both sides and improve the efficiency of the water resource allocation. However, under the existing water distribution system, the real water market has not been formed, although water right can be transferred among the users. The efficiency of the water resources allocation is still low.

2.4 The judicature lags behind the legislation concerning the Yellow River water law system, the compliance of laws should be strengthened

There are several major water laws governing the water affairs in China. These laws include The Water Law of the People's Republic of China, Soil and Water Conservation Law, and Flood Prevention Law of the People's Republic of China. The Water Law of the People's Republic of China provides the fundamental rules governing the definition, acquisition, and administration of water rights. It establishes very strict provisions and guiding principles concerning the ownership, allocation, and distribution of water resources. It is a general law for the entire country but fails to provide detailed measures for implementation. As a result, some of the provisions are difficult to be implemented in the real world. Since China's Criminal Law is based on the "statutory punishment" principle, any violations become punishable only when they are clearly stipulated in the law. Therefore, it is necessary to establish supporting laws and regulations, such as the Yellow River law, specific to the Yellow River valley. With detailed implementation procedures, the management and operation of water rights may become a reality. Considering the significance of the Yellow River in Chinese social and economic system, YRCC put forward to making the Yellow River law in 2000, and did a lot for this suggestion, the vice primer Wen Jiabao at that time suggested issuing the Yellow River Water Volume Adjusting Regulation because the relevant ministries' did not yet have common views on this point. The Yellow River Water Volume Adjusting Regulation took into effect on August 1st, 2006, which was regarded as a much more feasible and pertinent for the water volume adjustment. Now concerning the Yellow River water law system, the judicature lags behind the legislation. Strengthening the judicature of these laws and regulations is very crucial today in order that the laws and regulations can be put into practice and carried out to protect the Yellow River Water allocation and utilization.

3 Innovation of the existing Yellow River water right system – prerequisites and new ideas

It is very clear that the existing Yellow River water right system is not adequate and defective in operation, and it is necessary to reform and establish a comprehensive tradable water right system. Such a new water right system not only would allow quantitative allocation and management of water resources at the macro – level, but also encourages water saving at the micro – level. It would provide an opportunity for the sustainable development of the Yellow River, fundamentally reverse the water shortage situation, retard the process of water environment degradation, and eventually build a water – saving society.

The prerequisite for the existing Yellow River water right reform and innovation is to build controllable water conservancy projects. The majority of the water conduits along the Yellow River are natural soil canals. There is a serious problem of water loss in the water conduits as water is transported for irrigation. It is difficult to quantify how much water is actually used for irrigation. For example, the installation of a lining system for sediment canals helps prevent water loss. Studies showed that a 10% increase in the lining system would improve water utilization efficiency by 8% ~ 9%. With controllable water conservancy projects, it is possible to accurately quantify the water consumption, define water rights, and measure water utilization efficiency. In Ningxia Autonomous Region, the industrial sectors were asked to invest in agricultural irrigation canal linings. The irrigation water saved after the installation of the linings is allowed to transfer to the industrial sectors, which improved the efficiency of water utilization

There are several new ideas for innovating and reforming the existing water right system along the Yellow River. The construction of controllable water conservancy projects would provide a solid foundation for accurate quantification of water rights. It also helps define the availability of water for consumption at the micro – level. Based on water quantification, it is possible to introduce a meaningful market mechanism for compensable transfer of water rights among users. It may be necessary to gradually increase the water price, allowing the market system to set its price, which would compel farmers to save water and maintain the water conduits to their fields. The increase in water price would also provide revenue for maintaining major water conduits and canals. However, it is also necessary to consider the psychological effect of water price increase upon farmers and their ability to pay for water, the adjustment of water price must progress in different stages. The first step may be adjusting the water price to half the cost, then to 2/3 and the full cost, at last, allowing the market mechanism to allocate and distribute water resources. Finally, it may be necessary establish a comprehensive law system governing water affairs. Enacting the Yellow River water law by The National People's Congress can provide judicial and law enforcement structures. The new law would pave the way for a new water right system that is fully governed by the law.

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Practices and Discussion on Establishing Water – saving Society in Zhangye City

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Abstract: The northwest region of China confronts with the shortage of water resources and the wasting of water resources. Building water-saving society can guarantee to achieve a sustainable development of the region's economy and society. In this paper the authors systematically summarize the content and the practical experiences of developing water-saving society in Zhangye City. Fully considerate indexes are given to reflect water conservation level, ecology and economic development as a whole. These can be used for reference to solve the problem of water resource, to build water-saving society and to promote sustainable development of the region's economy and society.
Key words: the shortage of water resources, water-saving society, evaluation

Water resources which are the basic condition for mankind existing, producing, living are essential need for keeping ecological environment, protecting biodiversity, promoting a virtuous development of region's ecological system and guarantee to achieve a sustainable development of the region's economy and society. The communist party central committee puts forward building saving-society in views of a very large population and shortage natural resources to guarantee a sustainable development. Building water-saving society and keeping sustainable water resources utilization are the important for Zhangye City. Zhangye City is located in the middle reach of Heihe Basin. As economy development and population increasing, water resources utilization increases and ecological environment gets worse and worse in lower reaches. The state council pays great attention to ecological renovation in Heihe Basin. Zhangye becomes the first experimental water-saving society in 2002. After four years' work Zhangye has formed the operating mechanisms which include government apparatus regulation and controlling, market guiding and public participation. It raised the efficiency of water utilization and realized people, water, ecology in perfect harmony.

1 Water resources' general situation and utilization in Zhangye

1.1 Water resources' general situation

Zhangye is situated in the middle reach of Heihe Basin. The southern side of which is Qilian Mountain and the northern side of which is Heli Mountain. It is an oasis nourished by Heihe water Resources. Zhangye City includs Ganzhou, Linze, Gaotai, Shandan, Minle and Sunan countie, covering a space of 4.2×10^6 hm^2 and occupies 2.6×10^5 hm^2 cultivated area. The population is 1.28×10^6. It is a typical agricultural area. In this region annual rainfall is 127.5 mm and annual evaporation is 2,047.9 mm. The annual natural runoff of Heihe basin is 24.75×10^8 m^3, which consists of 15.8×10^8 m^3 (above Yingluoxia), 2.37×10^8 m^3 (above Liyuanhe), 6.58×10^8 m^3 from other tributaries, 1.75×10^8 m^3 under ground. The summed water resources volume is 26.50×10^8 m^3. In recent years per capita possess of water resources is 1,150 m^3 less than that of nationwide. The region's limited water resources can not support economic developing in high-speed.

1.2 Water resources exploited and utilization

In Heihe basin agricultural development started in the Han Dynasty. Five canals were built in the Tang Dynasty. From Qing Dynasty the irrigated districts in Gaotai, Minle, Shandan have been exploited. In 1950's the used canals have been rebuilt. The efficiency of water utilization in canals has increased from 10 % to 30 %. In 1960's concrete lining has been used in some important cannels and the efficiency of water utilization has increased from 30 % to 50 %. Till 1980's the cannels with lining have occupied 62.5 % of the operating cannels and the efficiency of water utilization in canals increased from 30% to 50 %. In 2001 central government confirmed the regulation programming of the Heihe basin in the near future. Big scale alteration of cannel system and water-saving engineering works were put up in Zhangye city. The efficiency of water utilization increased to more than 60 %. Till the end of 2002, the summed cannel length of each scale is 9,961.36 km.

2 Building water-saving society in Zhangye City

2.1 Connotation of water-saving society

Building water-saving society is a profound social change. Its essence is building water resources management system which based on water rights and water markets theories and self-controlling water-saving pattern. Water-saving society may progressively heighten water resources utilization efficiency and reach economy, resource, ecology in perfect harmony. Some experts define water-saving society as following: in the process of people life and working and in the exploitation and utilization of water resources, people are inculcated with the knowledge of saving water and water protecting. At the same time, with the guarantee of complete government system, function mechanism, law system and the participation of government departments, and the public and water resource consumers, the efficient and rational distribution of water resource and keeping sustainable development of region's economy and society will be realized by combination of some measures of legal, administrative, economic, technological and engineering measures with adjust of social structure.

2.2 Content of building water – saving society

Zhangye City is the main region consuming water resource in Heihe Basin. According to statistical data the volume of water resources consumed in this area occupied 82.6 % of the total consumption in 1999. Building water – saving society in Zhangye has two major objectives: the first one is insuring the realization of the 9 aim of the regulation programming of the Heihe Basin in the near future, which allocate Heihe water resources in provinces, the second one is maintaining the economical and social development of Zhangye, improving people's living standard, protecting region's ecological environment. The content of building water-saving society includes water-saving system building and water-saving economy building, water-saving technology building, water-saving project building, and water-saving culture building etc.

2.2.1 Water – saving system building

Water – saving building system which includes building laws and regulations, government system, function mechanism plays a key role for water – saving society building.

(1) Building water – saving laws and regulations

Building water-saving laws and regulations have been laid up the first place of building water-saving society. A series of regulations have been draw up which include "management means of economize on water resources" "government measures of water price" "transaction guideline suggestion of agricultural utilization water resources" "indexes of utilization water resources in agriculture, industry, ecology" "adjusting program on industrial structure" "adjusting plan on agricultural structure". All of these regulations' publishing have an important guideline, accelerating, guarantee affect for fixing control aggregate supply and demand and government index, adjusting economize structure, optimizing water resource distribution and improving utilization of water resources.

(2) Building water – saving government system

Water – saving society attached an importance to government system and established leading group, efficient water – saving office which individually performs organization and guiding, spread advanced high technology. Government offices have been established in every county. Water – saving society defined mission at different level offices and set up rewards and punishments system. In works report system, regular checkups, and timely sum up work experience have been founded. Through all of these government systems it can ensure system and measure carried out.

(3) Building water – saving function mechanism

Water – saving society has formed operating mechanisms of government apparatus regulation and controlling, market guiding and the public participation in Zhangye.

It brings government apparatus regulate and control into plays in water resources distribution and economic development. Government offices established systems, defined water rights, controlled aggregate supply and demand at different levels and distribute water rights to every family. It also fixed water resources utilization in proportion of industry, agriculture, living, ecology and unity of water resources government in town and rural area. The government takes unity of water resources planning, water utilization license distribution, water resources expenses and the quantity and quality of water government.

The water – saving society positively introduced market mechanisms and gave free rein to guiding affects of market to water resources distribution. Reasonable water price mechanisms have been established. It permits water resources to be transacted freely, cultivates water market, carries out water ticket system. Water tickets synthetically reflect right, quantity and price of water. The families buy water according to water rights ticket which can ensure control aggregate supply and demand, and improve water price.

The family association water resource of utilization has been set up. They are in charge of the cases about water, management and defending of field project. Irrigation office regularly announces the region's water resources condition, information of water price and irrigation system which can urge people to participate in building water – saving society.

2.2.2 Building water – saving economy

Building water – saving economy is the key of water – saving society. Economic construction adjusting is the foundation in building water – saving society. It insist on deciding industry, adjusting construction, adding aggregate supply and demand, promoting development through saving water and form four industries of developing new seed strains, livestock farming, fruits and vegetables, light industry raw and processed materials. Grain, industrial value and grass in proportion adjust from 48∶50∶2 to 42∶46∶12 and the water resources utilization of agriculture, ecology, industry and living in proportion adjust from 87.7∶7.4∶2.8∶2.1 to 80.2∶13.1∶3.8∶2.9 and economic growth rate increase 10 % through adjusting construction. At the same time, it strengthens the study of scientific price system of seasonal fluctuation and stratum water price to increase water resources utilization rate.

2.2.3 Building water – saving technology

Building water – saving technology is the precursor of water – saving society. It vigorously spread new crops, strains and skills. New seed strains and vegetables were develged. Different experimental bases have been set up in counties. Efficient water – saving skills of irrigation on the sheeting, covering with ground sheeting, drip irrigation and water transfusion piping are overall spread which raised water – saving benefit.

2.2.4 Building water – saving projects

Building water – saving projects is the chief content of water – saving society. Projects of immediate harness plan in Heihe basin are the major projects and some other projects are added which are important for building water – saving society. Water – saving projects include coordinated installation reforming in irrigated district, channel water holes merging, take water installation reforming, ecological protecting, sewage reutilization. All above created advantageous conditions for building water – saving society.

2.2.5 Building water – saving culture

Building water – saving culture is the soul of water – saving society. Improving the public consciousness of saving water and making people save water on their own initiative are a prerequisite to build water – saving society. In the course of build water – saving society all kinds of propaganda, film on a special topic, special column, publicity book, theatrical festival, save water training could be taken.

3 Evaluation index system of water saving and conservation society

Scientific evaluation index system are the base which reflect water saving and conservation society level. According to the connotation and goal of water – saving society, in the light of the principle of building index system, we should follow the principle of scientific, representative, comprehensive, dynamic, obtainable and regional when building index system. On the basis of above principles the author built evaluation index system of water – saving society including water – saving level, economic development and protection of ecological environment and resolved index system into target level, evaluation essential factor level and evaluation index level. Target level is the final outcome, evaluation essential factor level is the all main parts of water – saving society system, and evaluation index level is the amount index of essential factor (see Table 1).

Table 1 Evaluation index system for water conservation society in Zhangye City

Evaluation items	Index classify	Evaluation index
Water – saving evaluation index	Synthetical evaluation index	(1) Quantity of utilization water resources of per ten thousand yuan GDP (including industry, agriculture, service trades) (2) The rate of quantity of utilization water resources decreasing of per ten thousand yuan GDP (3) Input in saving water per square (4) Quantity of utilization water resources of people average (5) Quantity of utilization water resources of main products on industry and agriculture (6) Water resources utilization of industry, agriculture, service trades in proportion (7) Replace water resources with the other headwaters in proportion
	Water – saving government index	(8) Building managerial system and organization (9) Bbuilding institution system and statutes (10) Plan of building water – saving society (11) Building and carrying out of control aggregate supply and demand and government index (12) Setting up price system of saving water and avoiding pollution (13) Input in water – saving guarantee (14) Water – saving propaganda

Continud to Table 1

Evaluation items	Index classify	Evaluation index
Water – saving evaluation index	Agricultural water – saving evaluation index	(15) Main crop output per square water (16) Main crop irrigation quota (17) Utilization coefficient of irrigation ditch water (18) The rate of water – saving irrigation project acreage (19) Agricultural input in saving water per square
	Industrial water – saving evaluation index	(20) Industrial output value utilization water per ten thousand yuan (21) Utilization water per unit main industrial products (22) The rate of recycle of industrial sewage (23) The rate of dealing with industrial sewage (24) Industrial input in saving water per square (25) The rate of supplying water losses in tap water factory (26) The rate of discharging industrial used water
	Municipal and living water – saving evaluation index	(27) Quantity of living utilization water resources of people average in town (28) The rate of popularization of water – saving utensil (29) Living input in saving water per square (30) The rate of dealing with living sewage
Index of building ecological Ecosystem	Ecological utilization water index	(1) The whole ecological water quantity (2) Woods and grassland utilization water in proportion (3) Ecological utilization water
	Quotaecological ecosystem evaluation	(4) Natural woods and grassland's areas (5) Percentage of forest cover in the headwaters area (6) The area of desertification (7) The exploiting and utilization rate of water resources (8) Regional groundwater level descending range
Consult index of economical development	Economical development model and pace evaluation	(1) Summed GDP and proportion of industry, agriculture, service trades (2) Summed water consumption and proportion of industry, agriculture, service trades
	People's living level evaluation	(3) People average allocation income in town (4) Peasants average pure income
	Utilization water sequence and people's participate	(5) Frequency of dispute about water (6) The member of family association of utilization water resources in proportion (7) Frequency of hearing meeting about major water question

4 Key points of building water – saving society

On the basis of statistical data, all departments in Zhangye utilized 82.6 % water resource in Heihe River in 1999. Water resource utilization irrigatier of irrigation is 90 % that of Zhangye City. So it is impossible to build water – saving society without efficient utilization of water resource in irrigation. At present it is flood irrigation in Zhangye City. Agriculture saving water is the major field and the most potential. Both the proportion of utilization water resource and saving water potential considering agriculture saving water should be givepriority to the development and the key points.

5 Problems and suggestions

(1) Scientific and reasonable water price system is the main economic measure. At present agricultural water price level is 50 % of the cost. The charged price is low in irrigation area. Domestic water price of Zhangye is lower than that of other equal scale cities. Too lower water price can't act on water – saving. So next step we should quicken reforming water price system and set up scientific, reasonable, adapting to the region's water resources water price system.

(2) Perfect calculation installation is the significant guarantee of building water – saving society. At present calculation installation don't coordinate in the part region. The family utilization of water resources have not been perfect calculated. The form of charge for water calculation is coarse. So we should improve calculation installation when building system.

Building water – saving society has got some frints in Zhangye City. But it is just in the beginning, and there are also some problems exist. Now we should pay more attention to summarize experiences, analyze problems and study the ways of solving problems to achieve great successes in the next stage.

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Analysis of Water Price Adjusting Space of Agriculture Water Supply in the Lower Yellow River Irrigation Area (LYRIA)

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Abstract: Since 90s of 20th century, on the one hand, Yellow River water supply for agriculture has been becoming uptight in the LYRIA due to the continuous decrease of runoff flowing to the downstream (Huayuankou Section). On the other hand, the water conflict between demand and supply has been accelerated due to the under development of water saving agriculture which induced by so many restrictive factors such as the current management system, the collecting mechanism of water fee, water fee standard, water price level, etc. Based on investigation to the LYRIA, this paper puts forward the possible adjusting space of water price for agriculture water supply and its realization approaches via the analysis of the current water fee collection, water supply cost, water price, farmer's bearing capability, etc.

Key words: water price level, water supply cost, bearing capability to water price, adjusting space

Since the foundation of China, Lower Yellow River Irrigation developed very fast and now LYRIA is the largest gravity irrigation area of the country. Up to now, 98 irrigation districts have been built with an area larger than 10,000 mu each. All the 98 irrigation areas can be divided into two parts, one part contains 37 irrigation areas with a scale larger than 300,000 mu each and the other part 61 with a scale less than 300,000 mu each. The total planned land area is 96.12 million mu, farmland 58.37 million mu, designed irrigation area 53.69 million mu and available irrigation area 32.21 million mu. LYRIA involves 86 counties of 16 cities of Henan and Shandong Province. It plays a very important role for the economic development of the downstream region and the beneficial population is about 55.41 million.

Yellow River water supply for agriculture has a continuous decrease trend since 90s of the 20th century influenced by many reasons. Water amount decreased from 10.04 billion m^3 at the beginning of 90s to 61.12 billion m^3 in 2003 and 4.76 billion m^3 in 2004. The conflict between water supply and demand becomes seriously day after day. But there is a strange fact, on the one hand water supply is not enough, on the other hand unreasonable water utilization exists. The irrigation water utilization is about 0.3 ~ 0.5, very low (developed country about larger than 0.9). Compared with the developed country, there is a big gap in irrigation water productivity. The water saving irrigation area according to related norm is only 20%.

In some extent, low investment is the cause for low water use efficiency and water saving level, but the main reason is that water right and water market system has not perfected, the economic regulation role of water price has not been brought into play, farmer lacked of water saving consciousness etc.

1 The current water price criterion and water supply cost

The current water price in LYRIA in Henan and Shandong province includes water supply price of canal head, operation price of administrant unit and price of farmer organization.

For Henan irrigation area, the entrance of the main canal is the measuring point for water volume. The irrigation price for farmer is 4.8 cent/m^3. Among which, 4 cent/m^3 is according to government standard and the other 0.8 cent/m^3 is accessional part for the management of tertiary canal system. The three parts of water price is 1.0 ~ 1.2 cent/m^3 for water supply price of canal head, 2.8 ~ 3.0 cent/m^3 for operation price of administrant unit and 0.8 for farmer organization.

For Shandong irrigation area, the entrance of the branch canal is the measuring point for water volume. The current agriculture water price is different from place to place. The average price of the province is 5.045 cent/m^3. The price of Jinan city is 5.35 cent/m^3, Zibo City 5.0 cent/m^3, Jining City 4.88 cent/m^3, Dongying City 5.6 cent/m^3, Dezhou City 4.5 cent/m^3, Liaocheng City 5.0 cent/m^3, Binzhou City and Heze City 5.6 cent/m^3. Data of Shandong Province from 1999 to 2002 shows that 14.6% of the actual water charge received is for Yellow River department, 28.9% for irrigation area management unit and the others for local government.

According to the report of "Research on Yellow River irrigation water price of Henan Province", water supply cost is 12.0 ~ 20.0 cent/m^3 for the province, but the actual water price is only accounting for 24% ~ 40% of the cost. Water supply cost is 12.9 cent/m^3 for Shandong Province, but the actual water price is only accounting for 39% of its cost. So it is obviously that water supply cost and current water price is completely unconformity.

2 Farmer's water price

According the current water fee standard water charge is collected based on consumed water volume. But it is difficult to determine how much water farmer consume actually due to lacking of integrated measuring equipment. So water fee is collected in term of irrigation or agricultural population and this is also a common way for agriculture water fee collection of china.

Because the current water price standard is different from the actual water price for farmer, so the current water fee for farmer based on irrigation area or population should be changed to the price based on water volume which is called farmer's water price. The conversion formula is as the follows:

$$P = B/W \tag{1}$$

where: P is Farmer's actual water price (yuan/m^3); B is Total water charge collected from farmer (10^4 yuan); W is Water volume consumed ($10^4 m^3$)。

$$B = P_{water} * A_{water} + P_{dry} * A_{dry} + P_{lift} * A_{lift} \tag{2}$$

where: P_{water}, P_{dry}, P_{lift} are water price for paddy and other crops of the gravity irrigation area and for crops of the lifting water irrigation area (yuan/mu) respectively; A_{water}, A_{dry}, A_{lift} are area for paddy and other crops of the gravity irrigation area and for lifting water irrigation area (10^4mu) respectively.

2.1 Water charge standard

Table 1 shows the actual farmer's water charge in the LYRIA. Various standards can be seen such as standard according to land area, or population, irrigation area per time, etc.

2.2 Converted results for farmer's water price

Statistic data shows, the gravity irrigation area accounts for 75% of the total irrigation area. Paddy accounts for 4.2% of the total and the dry farming crops accounts for 95.8%. Based on Table 1, the water charge standard of Liuyuankou is chosen as the lower limit and Renmin shengliqu as the higher limit to calculate farmer's water price of Henan province which is between 3.6 cent/m^3 and 8.5 cent/m^3. The average water price is 26% higher than water price criterion of the government.

The gravity irrigation area of Shandong YR irrigation area accounts for 60% of the total irrigation area and the lifting water irrigation area accounts for 40%. Paddy area can be neglected because the area is very small. Based on Table 1, the water charge standard of Gaocun is chosen as the lower limit and value of "Report on YR water price of Shandong Province" as the higher limit to calculate farmer's water price of Shandong province which is between 8.1 cent/m^3 and 13.7 cent/m^3.

Table 1 Agriculture irrigation water charge standard of representative irrigation areas

Province	Irrigation area	Gravity irrigation area		Lifting water irrigation area
		Paddy	Rain fed	
Henan	Liuyuankou	22 yuan/mu/year	12 yuan/mu/year	7 yuan/mu/year
	Handongzhuang	7 yuan/mu/time	8 yuan/mu/time	
		20 yuan/mu/ year for rice transplanting		
	Renmin Shengliqu	7 ~ 10 yuan/mu/time		
		≤55 yuan/mu/year	≤32 yuan/mu/year	≤32 yuan/mu/year
Shandong	Panzhuang	21.42 yuan/mu/year		11.78 yuan/mu/year
	Gaocun	20 yuan/mu/year		9 yuan/mu/year
	Xingjiadu	70 yuan/person		70 yuan/person
	Dayuzhang	20 yuan/mu/year		20 yuan/mu/year
	"Report on YR water price of Shandong province"	28 yuan/mu/year		24 yuan/mu/year

From above analysis, conclusions can be made that the farmer's water price of the LYRIA is higher than the current water price criterion of the government. The farmer's water price of Renmin Shengliqu of Henan Province is 5.9 cent/m^3 and 23% higher than the current criterion 4.8 cent/m^3. The farmer's water price of Henan YR irrigation area is between 3.6 cent/m^3 and 8.5 cent/m^3. The lowest is 25% lower than the current criterion and the highest is 77% higher than the criterion and the average is 26% higher than the criterion.

The farmer's water price of Panzhuang irrigation area in Shandong Province is 7.6 cent/m^3 and is 52% higher than the current criterion of Dezhou City. The farmer's water price of Shandong YR irrigation area is between 8.1 cent/m^3 and 13.7 cent/m^3. The lowest is 44% lower than the current criterion and the highest is 144% higher than the current criterion and the average is 99% higher than the current criterion.

3 Analysis of agriculture water price adjusting space

3.1 The judgment criterion of farmer's bearing capability to water price

The previous research proves that the proper proportional range of agriculture water fee to production cost, agriculture production value, net benefit and the increased benefit by irrigation are 20% ~ 30%, 5% ~ 15%, 10% ~ 20% and 30% ~ 40% respectively. The proper proportional range are 15% ~ 20%, 10%, 5% ~ 10% and 10% ~ 15% respectively for the undeveloped region of our country,. The Yellow River downstream region is undeveloped area, so the latter proportions are taken as the judgment criterion of farmer's bearing capability to water price for the LYRIA (see Table 2).

Table 2 Research result on farmer's bearing capability to water price of our country Unit: %

Item	Water fee to production cost	Water fee to agriculture production value	Water fee to net benefit	Water fee to increased benefit by irrigation
General region	20 ~ 30	5 ~ 15	10 ~ 20	30 ~ 40
Undeveloped region	15 ~ 20	10	5 ~ 10	10 ~ 15

3.2 Income and payout of representative farmer

Irrigation areas such as Renmin Shengliqu, Wujia, Qucun, Liuyuankou of Henan Province and Weishan, Xingjiadu, Liucunjia of Shandong Province were selected as representative areas based on local characteristic, distribution etc. Thereafter the farmer's income and payout for agriculture production were investigated and the result was listed in Table 3.

Table 3 Average income and payout of representative farmer's agriculture production (yuan)

Province	Need pay fee	Actual pay fee	Agriculture production value	Total cost		Agriculture net benefit	
				Include labor	Notinclude labor	Include labor	Notinclude labor
Henan	207	119	5,764	3,323	2,090	2,441	3,674
Shandong		134	5,920	3,829	2,663	2,091	3,258

3.3 Analysis of farmer's bearing capability

For the representative farmers in Henan and Shandong provinces, the proportions of need pay water fee and actual pay water fee to agriculture production value, total cost and net benefit can be seen in Table 4.

Table 4 Farmer's bearing capability to water price

Province	Proportion of need pay water fee (%)					Proportion of actual pay water fee (%)				
	Agriculture production value	Total cost		Net benefit		Agriculture production value	Total cost		Net benefit	
		Include labor	Not include labor	Include labor	Not include labor		Include labor	Not include labor	Include labor	Not include labor
Henan	3.59	6.23	9.9	8.48	5.63	2.06	3.58	5.69	4.88	3.24
Shandong						2.26	3.50	5.03	6.41	4.11

The proportion of the average water fee of representative farmer of Henan Province, which is needed to pay, to agriculture production is 3.59%, to total agriculture cost is 6.23% (include labor) and 9.90% (not include labor), to net benefit is 8.48% (include labor) and 5.63% (not include labor). The proportion of the average water fee of representative farmer of Henan Province, which is actually pay, to agriculture production is 2.06%, to total agriculture cost is 3.58% (include labor) and 5.69% (not include labor), to net benefit is 4.88% (include labor) and 3.58% (not include labor). Compared with the related research result, the proportions of need pay fee to production cost, agriculture production value and net benefit are all intervenient or below the above criterion. The proportions of actual pay to the above items are even lesser. This means that farmer in Henan province has a certain bearing capability to water price and a certain adjusting space does exist.

The proportion of the average water fee of representative farmer of Shandong province, which is actually pay, to agriculture production is 2.26%, to total agriculture cost is 3.50% (include labor) and 5.03% (not include labor), to net benefit is 6.41% (include labor) and 4.11% (not include labor). Compared with the related research result, we can conclude that there is a large potential for farmer's bearing capability of Shandong Province.

Other more, investigation and analysis were carried out to 520 representative farmer families of Weishan and Liucunjia irrigation area of Shandong Province. The proportions of water fee to increased benefit by irrigation are 3.09% and 3.82% which is far below the judgment criterion 10% ~15%. This also means that there is a large potential for farmer's bearing capability of Shandong province.

3.4 Analysis of water price adjusting space

The agriculture water price criterion of LYRIA is relatively low and the average water price of Henan and Shandong Province is 24% ~40% and 39% of the water supply cost respectively. What ever from the point of agriculture production cost, production value, net benefit and increased benefit by irrigation, the current water price takes a very small part of every item. But at the present time, farmers in LYRIA are not so rich, if water fee took the whole net benefit, farmers certainly would reduce irrigation area or look for another water resource such as groundwater etc. And consequently local water resources and even local environment will be damaged, income of management unit will be decreased and cause difficulties for daily running. At last the purpose of adjusting water price can not be achieved. So it is impossible to achieve the water cost at one time and should be step by step taking into account the farmer's bearing capability to higher price.

Water price adjusting space was calculated from different index based on the analysis of farmer's bearing capability to water price. The differences between proportions of water fee to production cost, production value and net benefit and the judgment criterion represent the adjusting space (see Table 5).

Table 5 Analysis of agriculture water price adjusting space of DYRIA Unit: %

Item	Region	Criterion	Water fee to cost	Water fee to production value	Water fee to net benefit	Water fee to the increased benefit by irrigation
			15 ~ 20	10	5 ~ 10	10 ~ 15
Bearing capability	Henan	Need pay fee	9.90	3.84	5.63	
		Actual pay fee	6.95	2.06	3.23	
	Shandong	Actual pay fee	5.02	2.27	4.10	3.46
Adjusting space	Henan	Need pay fee	5.1 ~ 10.1	6.16	−0.63 ~ 4.37	
		Actual pay fee	8.05 ~ 13.05	7.94	1.77 ~ 6.77	
	Shandong	Actual pay fee	9.98 ~ 14.98	7.73	0.9 ~ 5.9	6.54 ~ 11.54

From Table 5 we can conclude that there is different adjusting space for different index when farmer's bearing capability to water price are taken into account for LYRIA. The largest adjusting space is the one for index of water fee to agriculture production, which is between 5.1% and 14.98%. The smallest one is for the index of water fee to net benefit, which is between −0.63% and 6.77%. The negative value means the proportion of water fee to net benefit is higher than the lowest limit of farmer's bearing capability. But generally speaking, there is a certain increase space for water price.

4 Approaches for realization of agriculture water price

Facilitating water saving and the farmer's bearing capability are a pair of contradiction. From the view of the government and its administration, water price is a little bit lower. From the point of farmer living on the farmland by contract, it is not appropriate to raise agriculture water price. So it is suggested that the current water price can be kept unchanged at the present time because the farmer's income is low under the current agriculture production operation model which is based on individual farmer family. When the dualistic structure of city and countryside is eliminated gradually and most of the surplus labor moves to the other domain from agriculture and when the intensive cultivation occurs, agriculture water price based on water supply cost can be taken into considered gradually.

Research on the reform of agriculture water price should be carried out not only metering, management and utilization of water fee its self, but also from social, population, resources and environment of our country. If so, reform of water price will be pushed in line with the development of national economy and the great effect can be achieved.

In conclusion, the adjustment of agriculture should be completed step by step according to local condition and gradually reach the cost price.

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The Preliminary Study on the Reform of Agricultural Water Rights System in the Yellow River Irrigation Area

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Abstract: At present, the utilization rate of water resources in agriculture is low. And proprietary rights and the right of using water resources are not clearly separated. Agricultural using water is wasted too much . Based on the present development of market economy in our country and the condition of the Yellow River irrigation area, the right of using water should not be transferred withou compensation, although there are some practice problems and difficulties needed to be solved as soon as possible during transfering. It is shown in the study that the realization of the Yellow River irrigation water compensable transfer would play very important significance to realize Yellow River water resources optimum allocation and to raise efficiency and benefits of water resource utilization . This paper studies the ways and means of compensable transfer of water rights in the Yellow River Irrigation areas and provides some suggestions.
Key words: agricultural using water, the Yellow River irrigation, compensable transfer, agricultural water rights system reformation

1 The present status of agricultural using water in China

The contradictory between the supply and requirement of water resources in China is very serious . The shortage of water resources is one of the major factors restricting the sustainable development of economy social . Water resources is a necessary condition for agriculture development. The water volume used in agricultural accounts for the great majority of water resources , in China it is 80 percent of the total consumption of water resources. Meanwhile, the water utilization efficiency in agricultural is low, the utilization ratio is less than 40%. Water resouces are wasted too much. In which, the major reason is that proprietary rights and the right of using water resources are not clearly separated . It is key to resolve the water crisis of our country how to improve irrigation water utilization , how to save water resources and how to improve the water resources utilization ratio. Since 1980s, the country has adopted many polices and measures to guide both sides to supply water and use water and stimulate enthusiasm of both sides . It shows very clearly that compensable the Yellow River irrigation water right transfer mechanism only do the first step and it needs innovation about how to improve it and how to reinforce the reform of water using management system, mechanism and technology.

2 The problem about water right in agricultural water using

Water right include a series of property rights related to water resources, such as proprietary right , servitude , usufruct, etc.. According to the disposition , water rights are divided into the private property and the public property right and how to dispose it is decided by the intrinsic and the external factors . The water resources has the multiple economic characteristics , such as circulation , scarce , nonsubstituted , vibration , and so on. Economist approval that what is scarce means the quantity is limited to the expense demand. The ecology function and the majority function of water resources cannot be substituted. Therefore, its scare degree will be enhanced. The circulation is recycling the water in the expense process with reasonable executive management program . During the circulation , there may present remarkable undulation characteristic , the condition is turbulent , unstable, uniformity, unpredicted, irregular.

Our country water law stipulates proprietary right of water resources belongs to the country . Since there has not carried on reasonable division and assignment , that causes "the cauldron water" phenomenon during water using and water resources are wasted seriously . The causes of "male tragedy" are the undefined system about water rights, the barrier of water rights transaction and the lacks of stimulating mechanism . As an example, upstream irrigate farmland use too much water , though Yellow River lacks water resources seriously and there is not enough water to irrigate farmland in downriver area. Because there is no driving mechanism and the peasant household's enthusiasm is not enough, they cannot benefit from saving water , on the contrary, they spend too much on the water saving construction, they cannot obtain the income anywhere. So they refuse to save water . Based on the benefit maximization principle , only when the benefit is higher than the cost , peasant households will take measures and new technology to save water . And the partial performance is how much expense is saved in water using. Therefore, the price of water resources and the division of water rights are the important attributions to stimulate water saving.

3 Analysis on agricultural using water in China with economic theory

With the development of social economy , the structure of water using in China has changed . It has changed the overwhelming majority agricultural using water to agricultural water, industry water , city life water , ecology water and environment water , and so on . In the future , the proportion of agricultural water will reduce . The farmer is the community needed to be protected . Agricultural water right should be solidified according to the present condition and the farms should be compensated through the compensable transfer of water right and the construction of water conservation infrastructure and the development of effective agriculture. From the macroscopic theory, our country has achieved great achievement in economic development, which has completed the primitive accumulation in industry. Now industry can return nurturing to agriculture. Only in this way, the justicially harmonious development of society can be realized.

The scarcity of water resources deteriorates increasingly . Water resources supplies are limited in irrigation area, the idea "supply based on demand" cannot be realized in water resources distribution. The balance on supply and demand in irrigation area is shown in Fig 1 . S_2 is the ideal

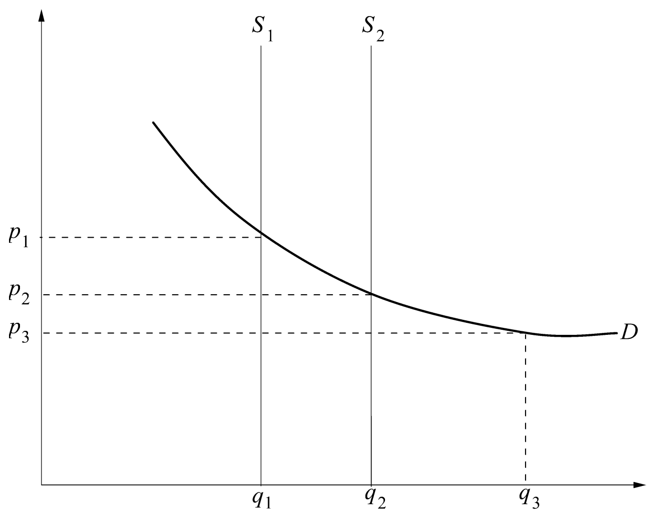

Fig. 1 The balance on supply and demand in irrigation area

supply curve when there is no leakage and waste during transportation and irrigation . S_1 is the actual supply curve , D is the demand curve of water resources . On the condition of S_2, the balanced price of water resource is p_2 and it is p_1 on the condition of S_1. At present, the agriculture water price is p_3 which is formulated and controlled by government , it cannot operate with market mechanism , and leads to the cost cannot be taken back and the excessive low price make the irrigation area loss . So the government has to provide financial subsidy . On the one hand , the loss is serious and they cannot construct water saving engineering . Many irrigation areas haven't been repaired for so many years , the leakage loss is serious . The average utilization ratio is percent 40 in the Yellow River irrigation areas . That is why the actual price is much higher than the theoretical balanced price . On the other hand , it is hiding way for the households to provide financial subsidy to irrigation area , which cannot reflect the lack degree of water resource and the consumed effective work during the producing and is disadvantage to renew idea and form habits to saving water, also enlarge the water demand excessively.

4 Application of water rights transfer in Ningxia Yellow river irrigation district

In the end of 2003 , Linwu power company, which is invested by Huadian power international corporation limited and Ningxia electricity generation group corporation limited, is one of the biggest beneficiaries in the experiment of water rights transfer in Ningxia Province . The industry in Ningxia has been developed not fully , the main reason is there is not enough water , although the Yellow River flows though Ningxia. Through water rights transfer , the industry has a reliable water resource, then the superiority on resources will be soon transformed into economical superiority. For many years , the industry, agriculture and ecological environment water in Ningxia have depended on the 4 billion m^3 the Yellow River water distibuted by government. And the water using structure is unbalanced , the agricultural water occupies the water volume above 95% and the industrial water only occupies 3%. It is predicted that the industrial water and city life water will get to 8.8 billion cubic meter, the lack of water will be the bafflement of the development of the society. Through the definition of water rights and the establishment of water rights system , some good measures should be taken so as to transfer water rights easily. When the industry has the ability to return nurturing to the agriculture, which will benefit to both of them. The Linwu electrical company has invested 30 million RMB on water saving project. When the project is completed, the enterprise can obtain 14.2 million m^3 water . The enterprise will demand 18 million cubic meter water when the 6 units power plants are completed till the 2010. The demand will be met. At present, the government consider the life of water saving facility, the water rights transfer period is 25 years. The price of transfer water includes the construction of the project, the maintenance, the renewal transformation, also includes the expense given to to the farmers, water management organizations and the ecology construction.

The significance of water rights compensable transfer in Ningxia is that it gives a successful solution in arid area. In the recent years , the natural water supply of the Yellow River was little, the contradictory between water using and supply deteriorate increasingly. On the base of agricultural water saving , through water rights transfer and water resources disposition , agricultural saving water will support industrial water and what's more it can help enhance water using efficiency . The solution is necessary for the economy and society development in the Yellow River irrigation area.

5 Study on water right transfer and compensation of the Yellow River irrigation area

Because of the serious waste and the too high irrigation proportion in the consumption of water resources, also industrial water and city life water grow sharply and too much agricultural water transfers into the non – agricultural use , the shortage of agricultural water resources has been intensified with the development of social economy recently. To establish the mechanism of agriculture using water transfer compensation is close related to the interest of farmers and the ecological environment in rural area, also is good for the alleviation of city life' demand of water and the development of the national economy.

5.1 Integrated management of water resource in irrigation areas

As a complete region , water resources of the Yellow River includes guest water and local water. The guest water is got with hydraulic engineering by management organizations. Some of the guest water is supplied to the households, the other is supplied to feed the local ground water . The irrigation water can be adjusted and managed effectively , but there is no effective management on extracting and using the ground water. The integrated management on the water resources in the irragated area is the only way to realize the integrated distribution and establish the foundation to the water transfer.

5.2 Compute the accurate quantity of water demand and improve hydraulic engineering facility

The transfer of irrigation water to non – agricultural using water involves the farmers' benefit . It is necessary to protect It is possible to carry on the transfer of water rights only if the farmers' legitimate benefit. The general questions in the downstream Yellow River are the insufficient irrigation engineerings, poor maintainence, low water price and the loss of every year. The irrigation utilization ratio is only percent 40. The improvement of hydraulic engineering facility is very important fos saving water and irrigation water rights transfer .

The science method for forecasting agriculture water demand is needed to compute accurate quantity of water eemand . And it should not only meet the need of irrigation water but also stimulate farmers to enhance consciousness of saving water.

5.3 Formulate appropriate price and benefit farmers

To a great extent, water rights transfer is related to economical issue. Formulating appropriate price of using water can give enough benefits to the householders who pay for water right transfer, which is helpful to promote saving water and sebsequently help irrigation water transfer to non – agricultural water . When the peasant households benifit from water rights transfer , they will save water by restoring hydraulic engineering facility by all means.

Firstly, the irrigation water price should carry on the compensation mechanism of "half cost price + subsidy from government". Compensation should be in accord with the water resources management which are controlling the total amount and managing in ration. Saving water is encouraged and government will punish those whose quantity surpasses the standard and provides subsidy to those whose quantity is lower than the standard. Next , it is important to establish compensation mechanism of agriculture using water . It's unfair for farmers to transfer water rights freely . Industry and city should return some money to agriculture for water transfer . Especially , when it is arid , industry and city domestic water should be guaranteed , at the same time , they should compensate agriculture. When farmers obtain benefits from water rights transfer , they will think over to save water , through improving the agriculture plant structure , making full use of sewage , and so on . Thus , the mechanism will play an important role.

6 Conclusions

With the development of social economy , it is imperative to transfer agricultural water into other use . The Yellow River crosses many administrative areas, there are many different irrigated areas conditions from the upstream to the downstream. It's wrong to allocate water rights in a exactly same way. According to the different situation in different areas, investigation and research should be actively carried on, and some typical areas should be investigated as pilot projects. On the one hand , water saving agriculture should be carried on , so as to transfer the saved water to industry or the city development; on the other hand , it is necessary to research how to protect the farmers' rights when transfer water as soon as possible promote development of industry and city.

Based on the successive experience of domestic and foreign area, the following suggestions are gotten according to the fact of the Yellow River irrigation area: firstly, transfer a part of water rights to the collective , the enterprise or the individuals through regulations; secondly, establish water resources transaction market to promote water resources allocated effectively according to the fair principle and the present situation. Finally, encourage enterprises or individuals invest on hydraulic engineering facility, thus both of the seller and the acceptor will obtain benefits.

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Study on the Connotation and Evaluation Index System of Water Saving and Conservation City

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Abstract: The conception of water – saving and conservation city puts emphasis on leading the brand – new water – saving idea into practice of urban economic development, realizing the coordinated development of urban economy, resource and environment while pursuing the object of high – efficient water – saving. The evaluation of water – saving and conservation city can comprehensively reflect the rational water – using efficiency in different levels. The evaluation index system involves five major aspects which include water – saving system, administrative system, ecosystem, economic development system and social security system.

Key words: water – saving and conservation city, connotation, evaluation index system

1 Connotation of "Water Saving and Conservation City"

1.1 Connotation of "Water Saving"

Literally, "water saving" can be interpreted as economizing water, but there is not a unified statement which accurately defines its connotation till now. According to the water law of Orleans state of U. S. A. , "Water Saving" has been defined as: through improving the technology of water taking, transporting and reclaiming, or through other permissive methods which can reduce the amount of water taking so as to satisfy the present water demand effectively. The domestic scholars have proposed a great deal of different opinions on the connotation of "Water saving" too (see Table 1). Synthesizing the views of different scholars, the connotation of "water saving "should include following basic contents: ①Water saving has the prerequisite of not reducing people's living quality and keeping the social economic development sustainable; ②Water saving does not simply mean restricting water supply, but mean the reasonable distribution and sustainable utilization of the limited water resources. Water saving also means the reduction of water loss and pollution during water taking and transporting; ③ Water saving depends on the improvement of water saving technology and the formal and informal institutional arrangement which involved water. ④The goal of water saving is to pursue and realize the benefit optimizing of economy, resources and environment.

1.2 Connotation of "Water Saving and Conservation City"

Opinions vary in the domestic definition about the connotation of "Water Saving and Conservation City" (WSCC). In 1996, "The guideline of Water Saving and Conservation City", issued by the Ministry of Construction, the State Economic and Trade Commission, the State Planning Commission, has defined WSCC as: through prediction and planning of water using and water saving, adjusting the structure of water consumption, and strengthen water management, a city can dispose and utilize the water resources rationally by the formed scientific water system. In accordance with the water resource quantity in this area and the local technological level, a Water Saving and Conservation City can make under control the quantity of water resources which needs by social – economic activities. From the view of sustainable use of water resources, Kuang Fengdi

(1991) has defined WSCC as "a city in which a good cycle of urban water resources utilization has been realized by comprehensive and reasonable utilization of it." Gong Ying et al (2003) view WSCC as a city that has achieved the water saving examine indexes which has been formulated according to the condition of local water resources and technological level, and its quantified indexes can also be used to assess the urban water saving. Xu Qiaoli (2003) has emphasized the difference of WSCC between narrow sense and broad sense. In narrow sense, WSCC can get the "double win" in reducing the quantity of water withdrawing water supply, and pollutants by improving the utilization efficiency of urban water resources. In broad sense, WSCC is an intact water saving system which perfectly combines the water using, pollution controlling and wastewater reclaiming to improve the water using efficiency.

Synthesizing every above – mentioned scholar's view, the author defined WSCC as following: Introducing the brand – new water – saving idea in the evolution of urban economy, we should scientifically confirm the index and quota of water using in every department. Based on water market, WSCC can form the good atmosphere of rational water resources utilization in the range of whole city, which would led to coordinated development of urban economy, resource and environmental. Particularly, by the methods of making the rational water saving goals, constructing the scientific system of water consumption, perfecting water saving legal system, water saving economic system and advanced water saving technology system, WSCC can realize comprehensive utilization of the urban water resource and rational distribution.

Table 1 Domestic scholar's representative views about water – saving connotation

Main viewpoints	Schocar and proposing time
1. The connotation of saving water includes developing the potential power of water resources, which means making full use of the regional water resource	Liu Changming (1996)
2. Water saving not only means that we should improve the productivity and utilization efficiency of water resource to maximum extent, but also means that we should reduce the net consumption of fresh water resources and water loss to maximum extent	Shen Zhenrong, Wang Lin (2000)
3. It is based on the rational productivity arrangement and production organization to save water. In order to accomplish social economic goal and sustainable development of social economy, we could rationally assign the limited water resource by adopting many kinds of measures	Dong Fuxiang, Dong xindong (2000)
4. Taking various kinds of measures, saving water just is the behavior that makes the quantity of water withdrawing per unit be lower than the quantity standard formulated by local government and industrial organization. Every behavior helping to reduce quantity of water withdrawing should be considered as water saving	Liu Geli (2001)
5. Water saving not only means to reduce the water consumption and restrict water supplies, but also to make use of the multi – function of water resources and the repeating use of water efficiently and rationally. That is to say water saving would help to get the best economic, social and environmental benefits on the condition that the water using is economicac	Chen Jiaqi, Wang Hao, Yang Xiaoliu (2002)
6. Water saving refers to develop the potential of the water resources, improve water using efficiency by taking the comprehensive measures. It includes improving the water using efficiency, reducing the pollutant discharging and coordinating the ecological environment	Chen Ying, Zhao Yong, Liu Changming(2004)

2 Evaluation content of "Water Saving and Conservation City"

There is not a unified WSCC evaluation criterion both in domestic and foreign now. Generally speaking, its evaluation criterion should be able to reflect the water resources carrying capacity, optimal allocation of water resources, water environment improving, and the coordination status between the water resources developing and the economy, resource and environment. Particularly, it should include the following seven major respects:

(1) Rationality of industrial structure. The special distributing of industrial structure is the key factor which influences effective distribution of urban water resources and development of urban economy. So we can start with a series of relevant evaluation indexes that reflect whether the industrial structure is rational.

(2) The implementation of water saving. Water saving planning should be made firstly in WSCC, and the implementation of water saving target is the important content to assess the WSCC.

(3) Water saving level of urban area. The high – efficient water conservation and rational water utilization are primary characteristic of WSCC, and the urban water saving level is an important factor in WSCC appraising.

(4) Water saving management level. It needs public participation and market regulation to build WSCC. Furthermore, the government's regulation and control are more important. So, the water saving management level of the government is extremely important for the effective implementation of water saving plan.

(5) Environment state of the urban area. The protection of urban environment and the state of urban ecological environment influence the improvement of urban water environment and the sustainable development of water resources directly.

(6) Public consciousness of water saving. The level of the public consciousness to water saving influences the efficiency of urban water using directly, thus influences the overall water saving level in the city.

(7) Development trend of urban economy. WSCC is a unity of urban water saving and urban development. The realization of the water saving goal in the city should not be at the cost of sacrificing economic development. On the contrary, there should be positive correlation between them.

3 Evaluation index system of "Water Saving and Conservation City"

Evaluation of WSCC can be understood as the assessment of urban water using efficiency by quantified indexes and the satisfaction degree to water utilization of social production and living. Because of the situation in each city differing in thousands way, it is very difficult to develop an operable management model based on the idea of WSCC if there isn't a set of evaluation index systems. So, we must structure a set of rational and scientific evaluation index systems which could reflect the whole characteristic of rational water utilization objectively and accurately.

3.1 Reviewing of relevant research achievemonts

The research of the evaluation indexes of WSCC in domestic academia involves two major aspects below:

(1) Evaluation of WSCC based on single water resource system. Zhao Huqiang et al (1997) has confirmed different consulting standard of water using quota per capita according to different cities have by applying "the law of quota index" to analyze water supply and water demand. He has also advocated to evaluate the WSCC by the index of urban living water saving. From the point of sustainable development of urban water resources, Zhang Xingfang (2000) has induced the indexes of water taking, water resources available in a city, water demand and water consumption to appraise the level of urban water saving, which based on the systematic dynamic theory. Zhang

Xiaojie (2001) has formulated a comparative integrated WSCC index system which combined two kinds of indexes of the urban water utilization efficiency and the shortage of urban water resources. Zhang Xiaojie et al (2002) considered that two kinds of indexes, industrial water reusing rate and water consumption, could not assess the urban industrial water saving efficiency objectively. They suggested that the industrial water saving index can appraise the urban industrial water saving efficiency according to different industries. Tan Hai ou et al (2002) combined quantity of industrial water saving, urban water saving approach and urban water saving goal to evaluate WSCC. They advocated that we should evaluate water saving mode and water saving goal separately. However, they have not done further research into how to appraise water saving effect of urban industry synthetically on the whole.

(2) Evaluation of WSCC based on the water resource – economy – ecology coupling system. From three aspects of water saving level, ecology construction and economic development, Chen Ying et al (2004) have formulated a set of water conservation society (WCS) evaluation index system which is suitable for the general region or basin. This index system includes 3 first grade indexes, secondary indexes and 51 tertiary indexes. In "Evaluation Indication System of Water Conservation Society", Chen Ying et al established a set of WCS evaluation index system from four respects of water saving level, ecological environment building, economic development and living security. This index system includes 2 first grade indexes, second indexes and 26 tertiary indexes. These creative researches mentioned above will be valuable references for the establish ment of WSCC evaluation index system.

3.2 Evaluation index system of "Water Saving and Conservation City"

We could construct the WSCC evaluation index system from six major aspects by synthesizing all kinds of research achievements and combining the connotation and evaluation content of WSCC, which are the water resources system, water saving system, water saving management system, ecosystem, economic development system and social security system (see Fig. 1).

(1) Water resources system. Urban water resources assessment is the basic work for the WSCC evaluation, which includes natural state evaluation and social state evaluation.

(2) Water saving system. The urban water saving system can be appraised from two aspects of the overall level and the levels of each sector. We could choose indexes which indicate the systematic development characteristic and the degree of coordinating among the subsystems from the view of macroscopic in comprehensive evaluation indexes. Comprehensive evaluation indexes are important parameters of comprehensive appraisal of WSCC. Water saving evaluation indexes of each sector is composed of indexes which linked with utilization of water resources closely and indexes which could reflect water needs trend in society. These indexes can reflect the allocation and utilization efficiency of water resources in the social economic system.

(3) Water saving management system. We can not establish the target of WSCC reasonably and implement the WSCC scheme effectively without scientific water saving management which restricts the development, utilization and conservation of urban water resources directly.

(4) Ecosystem. The ecosystem is a physical environment on which urban water resource system and social economic development depend. Therefore, the content of ecosystem evaluation includes the state of ecological water, ecosystem and ecological management.

(5) Economic development system. Implementing the strategy of WSCC construction, we should not merely seek water saving and improvement of ecosystem, but should seek sustainable development of the society and economy, which could help realizing the unity of water saving and social development.

(6) Social security system. The social security system can offer the foundation for realization of the goal of WSCC. Water saving scientific research and facility construction, water using order and public participation are all important contents of social security system of the WCSS.

In a word, the block diagram of WSCC evaluation index system mentioned in this essay just offered a general thinking for designing evaluation index system of WSCC. When we use the

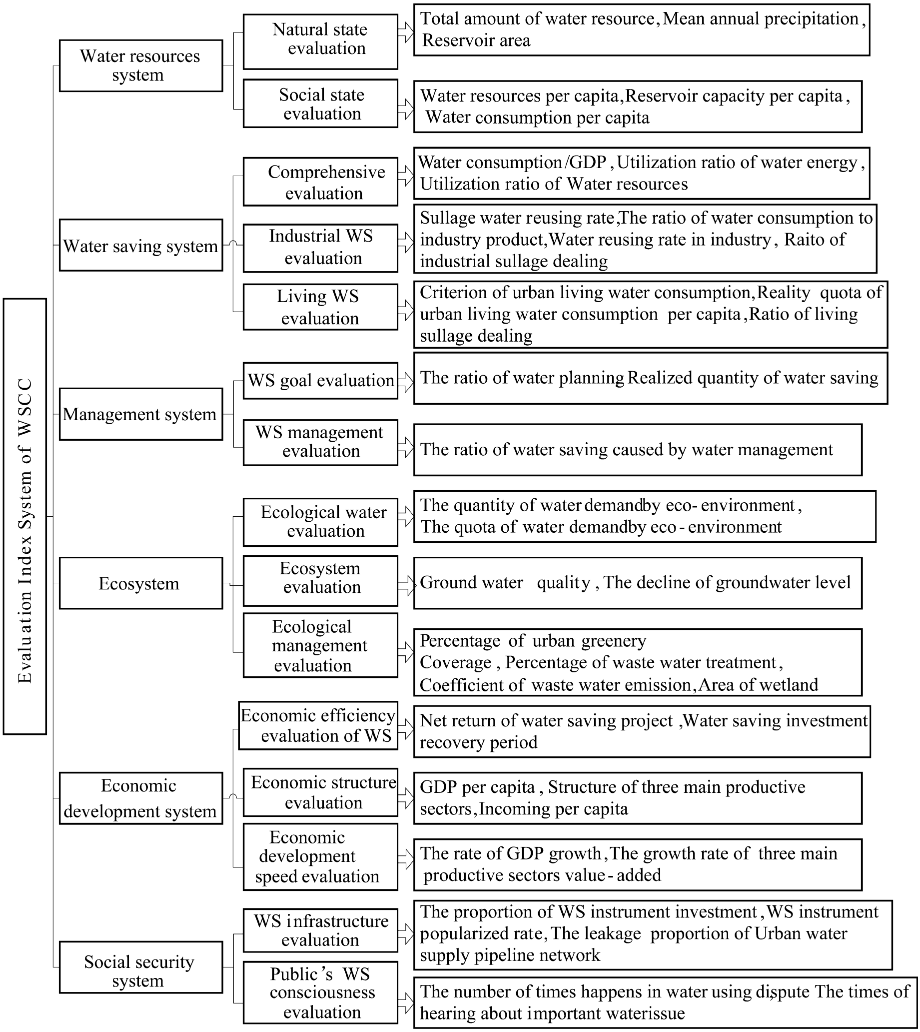

Fig. 1 WSCC evaluation index system block diagram

evaluation index system, according to its priority area and actual conditions, every city could analyze supplement and chose different relevant indexes to make suitable WSCC evaluation index system.

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Strengthen Water – saving Transformation in Irrigation Areas to Prompt the Sustainable Use of Water Resources of the Yellow River

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Abstract: This paper analyzes the grim situation that faced by the water resources of the Yellow River and discussed the importance of the water – saving transformation of the Yellow River. Through the analysis of the benefit that made from reforming of Taochengpu irrigation area, a suggestion is put forward that the water – saving reformation in irrigation districts is a foundational way to prompt the sustainable use of water resources of the Yellow River.
Key words: water resources, water conservation, reformation, benefit, sustainable use

As the cradle of the Chinese nation, the Yellow River, which is named "mother river" of China, has enriched the industrious and courageous people on both sides of the straits as well as brought them bitterness and hardship in the past thousands of years. Before the liberation, the Yellow River was like a defiant dragon raging in the vast land of China, the number of tragic scenes was shocking! It was really a case of "thousands of its merits, and who has final say?" After the birth of the New China, Chairman Mao inspected the river in person, issued that "the affairs of the Yellow River should be done well," therefore, to "tame the yellow dragon to bring benefit to people" became the common aspiration of the whole nation. Since then, the Yellow River has opened a new chapter in its history. However, as the continuous expansion of the water diversion project on the downstream, the contradiction between the supply of and demand for water keeps increasing, which cases a potential crisis to the sustainable use of the water resources of the Yellow River, flow dry – off, riverbed rise by siltation, water pollution, environmental deterioration, social turmoil and so forth, all these cause our mother river lost her former glory. The author will talk about the superficial views on the methods to prompt the sustainable use of the water resources of the Yellow River, standing on the perspective of the efficient irrigation transform in Taochengpu, Yanggu Country, Liaocheng City.

1 The grim situation that the Yellow River water resources are facing

The Yellow River originates from the Qinghai – Tibet Plateau and flows through Qinghai, Sichuan, Gansu, Ningxia, Inner Mongolia, Shaanxi, Shanxi, Henan, and Shandong provinces, with a total length of 5,464 km and a drainage area of 795,000 km^2. The estuary of the Yellow River is mainly from the towns above Hekou and Huayuankou, and the annual runoff accounted for 55.6% for towns above Hekou and 42.5% above Huayuankou, besides, from July to October, the main season accounted for 60%. It is measured in 2005 that the runoff of the Yellow River in Huayuankou Station is 25.7 billion m^3, except for the 72 million m^3 used below Lijin Station, the annual amount of the water in the Yellow River that flow into the sea is 20.408 billion m^3. Also, the statistics shows that there are 171 reservoirs both large and medium – sized, including 23 large reservoirs in the Yellow River Basin (compared with 2004, added a large reservoir on the mainstream in Lijiaxia and 6 medium – sized reservoirs on the tributaries in Ningxia). All these ensure the demands for water resources for agricultural and industrial needs and ecological environment protection for the downstream areas.

Along with the economic development, industrial and agricultural water consumption has increased, the contradiction between the supply of and the demand for water is aggravating day by day, recently, more than 4,600 water diversion projects and 29,000 water lifting works have been completed, making the design capacity of the tributaries more than 6,000 cubic meter, only in the downstream of the Yellow River, it provides water for the Huaihai Plain for more than 100 flood gates and pumps, causing flow depletion of the Yellow River for 20 years in the 26 years from 1972 to 1977 with a total length of 704 km, setting a remark in the history. No water flow into the sea for more than 300 days caused an economic loss of 13.5 billion yuan in Shandong Province. The dry – off of the Yellow River in recent 20 years brought great loss to the drinking water, the industrial and agricultural production, and the ecological environment in the lower reaches of the Yellow River from 2000 onwards, serous precipitation in the upper reaches of the Yellow River region for 3 consecutive years, as a result, inadequate water from the Yellow River continued weakening, appeared a dry phenomenon rarely seen in the history. July,2002 to October,2002, the main water supply zone of the Yellow River stood only 13.6 billion m^3, setting a fewest remark ever since 1950 from when the record can be founded. 2003 is the driest year to the Yellow River since the founding of the New China when the main stream can provide water for only 11.7 billion cubic meters, which means that even if we "eat out" the Yellow River, the supply and demand gap would still reach 5 billion m^3. According to the international standards, the utilization of rivers should be kept in 40%, however, to the Yellow River it reaches nearly 70%, exceeding the carrying capacity of the Yellow River water resources. It is understood that at present, the irrigation areas of the Yellow River has been increased from 12 million mu early the New China to 110 million mu today, the annual use of water resources reach 28 billion m^3, accounting for 92% of the river water. Meanwhile, the Yellow River irrigated areas have become major water wasters. It is estimated that by 2010, there will still be 4 billion m^3 shortage of the water even when we encountered a normal water supplying year.

Based on the analysis of economic and social development trends and the capacity of using the water in the Yellow River of the provinces, autonomous and regions that use the Yellow River water resources, if we do not take effective measures to control the drinking water, the dry – off of the Yellow River will become serious and will expend gradually with the increase of various water consumption, at last, the Yellow River may become a seasonal river. Flood control is a task that only focuses on flood seasons of the Yellow River, but to ensure the crisis and ecological balance is an arduous task that should be done every day, in every area without the consideration of time or place. To ensure that the Yellow River will not stop flowing has become quite an important task to control the Yellow River in the new century.

Facing such serious situation, many suggestions that were put out by experts reach a conclusion that to ease the contradiction between the supply and demand should focus importance on the saving of the river water, and the focal points of water – saving are in the irrigation areas.

2 Strengthen the water – saving transformation in irrigation areas to prompt the sustainable use of water resources of the Yellow River

2.1 The importance of the transformation of water saving in irrigation areas

Taochengpu Yellow River irrigation district, located at the southern part of Liaocheng City, Shandong Province, was established in 1988, using the loan of the World Bank, part of the project was put into operation and produced a marked effect in the same year. There are irrigation canals, desilting basins, north – south chief channels, and 31branch channels including 1.5 million mu setting basin, 91.4 km chief channel and 254.27 km branch channels. The irrigation areas are equipped with two large pumping stations with a total installed capacity of 3,340 kw, and a water – lifting capacity of 41.76 m^3/s. Also there are 2,005 all kinds of ancillary buildings in the irrigation district with a total fixed asset of 105 million yuan. Until 1998, the amount of the diversion water there reached 900 million cubic meter, which make an average of 600 thousand mu of irrigated area of 1.36 million mu; 2,275 kg water output for every million yuan agriculture, 150 kg water consumption every person everyday in the urban and 100 kg in the country, 431,298 kg grain yield, 1,045,243 crop yield, 3,763,598 million GDP, the per capita annual income of farmer is 3,730 yuan.

However, a number of problems had revealed in the past ten yeas in the irrigational district. Firstly, the low rate of lining water channels, aged building needs repairing badly, and canal seepage loss is great. The length of the main lining channel is only 2.0 km and the branch only 2.4 km, the water utilization coefficient is 0.45, and disrepair rate of canals accounts for 50%, which greatly effect the normal operation and irrigation benefit generation. Secondly, the projects in the field can not form a complete set and the technique for irrigation fall behind. The standards of the projects in the field is generally low, there are mainly soil drainages which have poor engineering match rate and poor level rate. The main form of irrigation is flood irrigation, series irrigation and pond irrigation, the water utilization is generally between 0.6 ~ 0.7, that's a serious waste of water. Thirdly, the management of the irrigational district is backward, the price system is unreasonable. The administrative office assumes sole responsibility for its profits or losses. Therefore, administrators cares more about their own economic interests, only concerne about saving water in key channels, instead of in the field, consider raising water prices, collecting money for water using, and one - sided pursuit of economic units as the starting point of irrigation management. These unbecoming ways severely constrained the economy's sustainable development of the agriculture in the irrigation areas. Aimed at these problems, workers in the Administrative Office of the Taochengpu irrigation area implemented a series of comprehensive measures to transform the water utilization. They insisted in that water - saving should be the core, they actively implemented the new water - saving irrigation technology, perfected the management of the irrigation district, deepened the reformation of the organization system, also, they established a reasonable price system of agricultural water, and improved the utilization of irrigation water, eased the contradiction between supply and demand of water resources in irrigation area, prompted the healthy operation of the management and the sustainable and stable development of the agricultures and industries. Above all, the transformation can not only the water resources but also decrease the working time of the pumping station, saving both water and electricity, it is essential to the establishment of a conserve and harmonious society.

2.2 Water - saving measures taken by the transformation

As there is a target of 91 million m^3 but a designed consumption of 280 m^3 meter in Taochengpu, big shortfall exists every year, the Yellow River resources become increasing tense, therefore, the development of water saving projects and the improvement of the irrigation technology is the centre of the building and management of the irrigation work. Managers in Taochengpu full played the enthusiasm of the local government and the people, in accordance with the principle that those who will benefit will be responsible, they attract and mobilize the masses to carry out large - scale farm water conservancy construction in many ways and at different levels. They began the transformation in 1998. The main approaches are as follows:

(1) Project measures: Firstly, they built 20 km main lining channels and 18 km branch channels. Building lining channels is most widely used as a measure to prevent water leakage, and it is proved that after the work, 70% ~ 90% of the water leakage are prevented, and more than 95% of the leakage can be prevented if concrete composite panels are used. Secondly, two U - shaped buildings that can irrigate areas of 52.5 thousand mu were established, possession of 45.5 thousand mu by pipe irrigation and of 1 million mu by spray irrigation. The experiments showed that over the soil drainage pipe 95% ~ 98% water leakage can be reduced, 15% ~ 20% seepage losses can be saved and 10% production can be increased, saving significant increase efficiency. Thirdly, to promote the irrigation used by the xiaobailong plastic pump for areas of 96 million mu, which is featured of low cost, clear water - saving effect and convenient management operating. At last, it was the supporting projects. A total of 176 buildings are modified, 156 new channels were

expended, and 9.6 million m^3 of the soil and rock work was finished. All these measures cost a total investment of 45 million yuan.

(2) Technical measures: The first is to strengthen the irrigation water distribution. Radio communication network were established to ensure the water management in a timely feedback. Second, a rational exploitation of the ground water was made. 126 thousand mu were irrigated from the wells, 130 million m^3 were exploded on the ground in 2002, which greatly eased the contradiction, so in 2002, a great drought occurred, but a bumper crop. The third is a large - scale implementation of the narrow, short bed. By 2005, the area has reached 690 thousand mu, accounting for 66% of the total area of irrigated areas. The forth is to store water in winter and irrigate in spring and store when wet and irrigate when dry to supply the groundwater reasonably.

(3) Policy measures: Firstly, it needs control the total amount of the water consumption, and settles the water - saving supply according to the demand. Secondly, it is necessary to establish the water - saving operational system from top to bottom, Taochengpu administrative office as the authority. Thirdly, it should reform the irrigation district, and definite the rights and responsibilities of everyone. Forthly, implement measures that charge by the amount of water consumed. To the end of 2001, 16 towns of Yanggu county have realized the fact that charge by the amount of consumed water is more reasonable. Fifthly, enhance the water price. The collect fees of the Yellow River by non - standard dry season by the State raise from 1.2 fen per cubic meter 1998 to 4.5 fen per cubic meter 2002. Sixthly, to do propaganda and mobilize the enthusiasm of importance of water - saving, approaches and methods of that in many ways, try best to leave the farmland and narrow the width of the land and use the xiaobailong plastic pump to irrigate with the ability of the presents.

2.3 The benefit that brought by the transformation of the irrigational district

(1) Direct benefits: As the water - saving transformation has been put into operation, the effective irrigation area increased from 600 thousand in 1990 to 850 thousand mu in 2005, and compared with 1990 ~ 1998, the annual irrigation area reaches 250 thousand mu from 1999 to 2005. We count the increasing money every mu as 48.4yuan, thus 12.1 million yuan are put out every year. As to the water quantity, the average annual consumption of the water from 1999 to 2005 is 81 million m^3, compared with the year before 1999, 19.4 m^3 water was saved per mu and per time, saving 0.87 yuan per year per mu, thus 1.827 milion yuan were saved in the whole irrigation area.

(2) Indirect effects: The water - saving transformation in the irrigated area saves the water resources of the Yellow River and expends the actual irrigated areas. From 1999 to 2005, the water utilization rate increased from 0.45 to 0.61, at an average that saving 90 million m^3 and 1.08 million yuan every year. Because of the water - saving, the cost of collecting water is reduced, therefore, the two pump stations, Nanxu Station in the south and the Luotuoxiang Station in the north, can save electricity of 990 thousand kilowatt every year, which means 545 thousand yuan and can reduce sediment of 100 million m^3 meter every year, which can save more than 3.5 million yuan that used for sediment desilting.

(3) Social benefits: Firstly, it keeps high incomes of the presents and maintains social stability. Second, it makes a contribution to maintaining a healthy life by saving water resources so as to ease the contradiction between supplies for and demands of water resources in the Yellow River areas. Third, it keeps a certain amount of water that flow into the sea, ensured the ecological balance of the downstream of the Yellow River.

3 Conclusions

Taochengpu Irrigational District is one of the largest irrigated areas in the middle and lower reaches of the Yellow River. In recent years, through the implementation of a comprehensive transformation of the water, it makes more notable results: it makes a contribution to the sustainable use of water resources of the Yellow River and achieves a win - win situation between the Yellow River and farmers. In the lower reaches, there exist 94 culverts diverting water from the Yellow

River to irrigate more than 36 million mu of the farmland in the Yellow River, and the average annual water diversion is nearly 10 billion m^3. If all the area can save water and carry out the transformation, with an average annual saving of 2 billion m^3, it must be a great strategic significance of the sustainable use of water resources of the Yellow River. However, the situation as the Yellow River basin management should carry out some encouraging policy to ensure that this endless flow of the mother river, such as saving water, a planned diversion, the water supply agreement, the ultra primers increase the dynamic value; on the financial side, the good water – saving irrigation areas, the state must show a certain amount of funds to award, replace subsides with awards. We can use these methods to encourage the water – saving irrigation areas to carry out the transformation, in order to promote the sustainable use of water resources in the Yellow River.

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Calculation Method Improvement of Single Measure Water – saving Quantity in Comprehensive Water – saving Reconstruction for Irrigation Areas

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Abstract: The irrigation area's water – saving reconstruction often adopts many kinds of measures synchronously, and irrigation area's water – saving quantity is the comprehensive effects of all single measures. The present water – saving calculation method, which is unable to satisfy the practical development's needs, has deficiency in evaluating the contribution of concrete water – saving measures to the comprehensive water – saving quantity. Therefore, it is necessary to develop a set of computation methods, which is able to reflect the water – saving effect of a single measure, also express the synthetical water – saving quantity. This article analyzes various links' water demand from water source to the crop's absorption and the principles of water – saving measures, combines organically the water – saving quantity of a single measure method and the overall method, and proposes a set of calculation methods with no repetition and really reflecting the real water – saving contribution of each single measure.

Key words: irrigation area, comprehensive water – saving reconstruction, single measure, water – saving quantity, calculation method

At present, the irrigation area of the Yellow River basin has amounted to 110,000,000 mu, which is the whole basin's and even the country's important grain and cotton production base, and the main body of consuming the Yellow River's water resources as well. According to statistics, the water consumed by the farmland of the Yellow River basin occupies 76.0% of the basin's total water consumption, but even reaches as high as above 90% in the arid and semi – arid areas like Ningxia and Inner Mongolia irrigation areas. Influenced by many kinds of factors, the irrigation water use coefficient is not high, only about 30% ~ 40%. In order to satisfy the regional socio – economic development and our country's food security in the future, the water – saving reconstruction project in large and middle scale irrigation areas was implemented in 1998, and auxiliary project supplement and water – saving technological reconstruction for national 402 large and middle scale irrigation areas were successively carried out, which greatly enhanced the irrigation area's water use efficiency. But compared with the developed countries, there was still a big gap and had big water – saving potential, so it needs to go on adopting water – saving reconstruction in large – scale irrigation area. In order to obtain a good economical water – saving benefit in the water – saving reconstruction, it is very essential for the irrigation area to select the water – saving measures suitable to the local actual situation and having the good water – saving effects when making the irrigation area's water – saving plans. Because the water – saving quantity is the main index to weigh the water – saving measure's effects, its computation becomes the fundamental link in selecting water – saving measures.

In view of the present situation of irrigation area's water usage and the regional industrial development's water demand, the experimental work of water right transform in Ningxia and Inner Mongolia has been made. The water right owners (mainly the agricultural water user), through taking various water – saving measures, save some water and then transfer them to reception party (mainly the industry user) at some cost. The agricultural water user will obtain the water – saving fund, and simultaneously provide the water resources to support the industrial development, which will be a win – win game. A key technology in water right transferring process is how many water resources can be saved after the engineering measures are adopted. It relates to the water right transformation quantity, and also is the base to compute the water right transformation's expense. Therefore, it is necessary to research the water – saving quantity calculation for the benign operation of water rights and water market.

In order to scientifically evaluate the water – saving effects of different measures in the irrigation area, this paper proposed some water – saving quantity's computation methods for different water – saving measures. But, as for the irrigation area, water – saving reconstruction does not refer to just a single technique or measure, but the synthesis of many kinds of water – saving technologies. As a result of the lack of the interacting analysis of various water – saving technologies, some problems existed in evaluating the water – saving effects.

1 The present water – saving calculation method and the existing problems

1.1 The present calculation method of water – saving quantity

Domestic research of water – saving quantity started from single item measure, and at the present stage it is still the main method for its calculation. Along with the practical development, the regional water – saving reconstruction is being developed from a single water – saving measure to synthetical water – saving measures. At present, there are two major computation methods adopted in the comprehensive water – saving reconstruction for the irrigation area:

(1) Sub – item computation method: obtain the synthetical water – saving quantity through directly summing up of all single items, for instance, Wei Yuanming, et al. after investigated the data from Hexi Corridor in 2000, and consulted with 2005's water – saving irrigation and development plan, calculated the synthetical water – saving quantity using spray, micro fills and tube fills irrigation methods and so on to substitute the flooding irrigation. The computing procedures can be seen in Fig. 1.

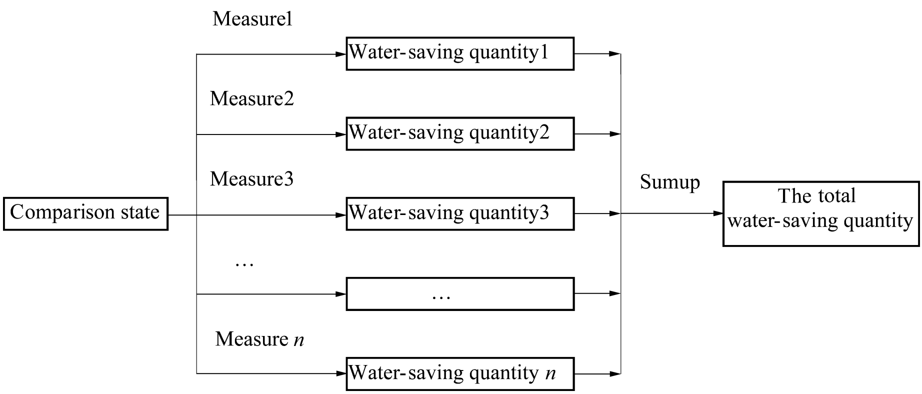


Fig. 1 Sub – item computation method

(2) Overall computation method: If the essential factors of water demand, after many water – saving measures are implemented, can be obtained, we can work out the synthetical water – saving quantity through the computation of water demand before and after measures are implemented. Fu Guobin, Tian Yutsing, Ou Jianfeng, Ren Chunxia, et al. embarked from the crops' water demand, considering the possible utilization degrees of every link in the planning irrigation process, such as effective precipitation, ground water, water distribution, field water use, transpiration, and analyzed the possible efficiency and the usage in every link, finally formed a theoretical computation method of water demand. Through comparing with the present irrigation water's consumption, the possible water – saving quantity was computed; Shen Qiangyun, etc. calculated the synthetical water – saving quantity for the planting structure adjustment, the water – saving technology's supplement project and the anti – seepage of ditches and canals in analyzing the Ningxia Yellow

River irrigation area's water – saving quantity,. The computation procedures can be seen in Fig. 2.

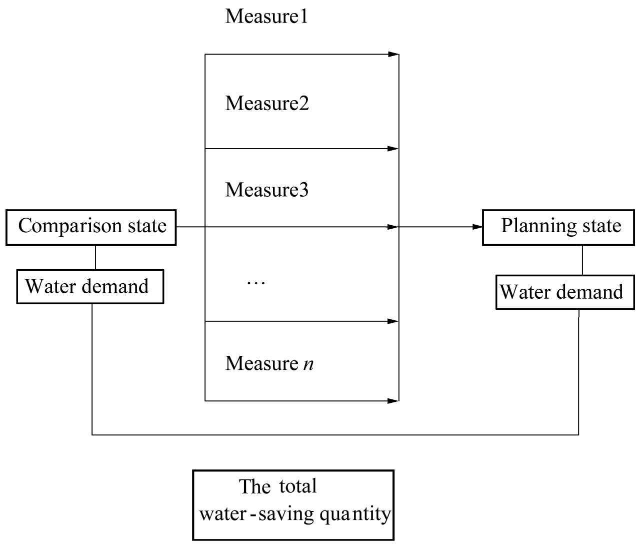
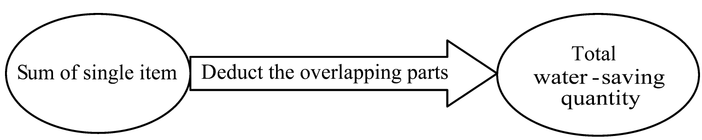


Fig. 2 Overall computation method

1.2 The existing problems

The water – saving quantity calculation method for single item measure in the irrigation area is mature at home and abroad, but there are certain problems in the calculation aspect of synthetical water – saving quantity. The computation for the overall method is quite simple with a clear concept, but it is unable to represent the single item's real contribution. Although the sub – item computation method can calculate the water – saving quantity of single item, the result after summing up is bigger than that by the overall method's computation, so it must deduct the overlapping parts from the irrigation area's synthetical water – saving quantity as shown in Fig. 3. But for water – saving quantity computation of overlapping parts, there is not an effective method at present. Therefore, water – saving quantity calculated by this single item method cannot really reflect its real contribution to the irrigation area's water – saving reconstruction.



Sub – item computation method Overall computation method

Fig. 3 The relationship between the two methods

2 Water – saving irrigation measures and principles

2.1 Process of water demand in irrigation area

Irrigation is the manual technical measure to supplement the water demand from farmland crops. An irrigation process consists of four parts: firstly, a certain volume of water from different water sources such as surface water (rivers, lakes or reservoir), ground water and so on are taken; secondly, the water taken is distributed to the field's water inlet through all levels of big and small channels; thirdly, the crops are supplied with the distributed water (ground furrow, ditch fills, spray irrigation, micro fills and so on); finally, the crops' roots absorb the water to grow up and form its output in kind. During the processes, some water will be lost by evaporation and leakage, and the rest can be absorbed by them at last. So the water taken by the irrigation areas must consider the field and channels' evaporation and leakage. The irrigation area's water demand process can be seen in Fig. 4.

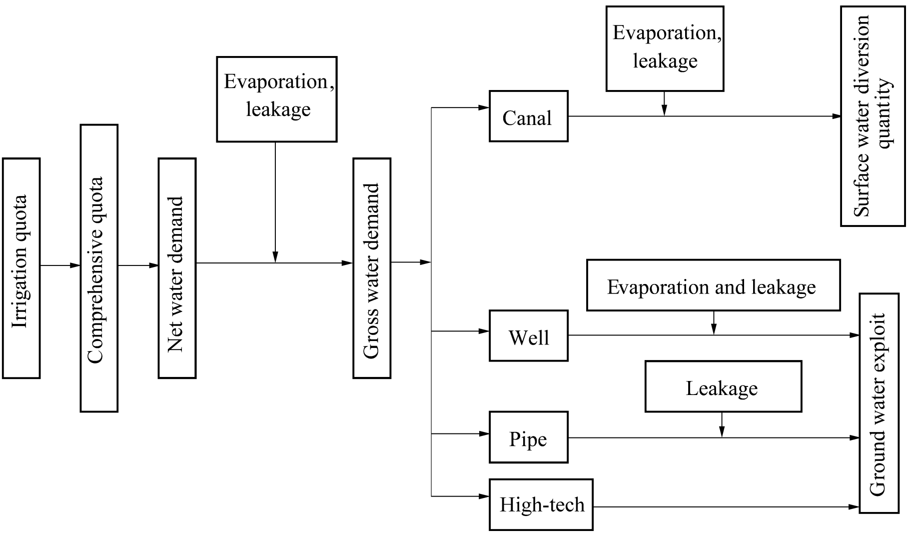


Fig. 4 Water demand process in irrigation area

2.2 Classification of water – saving irrigation measures

At present, the water – saving measures used by various countries may be basically classified into the following: engineering measures, biological measures, agronomy measures, exploitation of new water sources, management and so on.

(1) Engineering water – saving measures: The kind of measures may further be divided into three categories: ditch distribution's water – saving measure, field irrigation's water – saving measures and ditch – well water – saving measures. They include the construction of water transfer project, ditch anti – seepage project, pipeline water transfer, water – saving irrigation technology (tube fills, spray irrigation, drip irrigation and so on), greenhouse application and so on. The main function is to reduce the loss (including reducing the ditch's waste water and field drainage) of ditch's water transfer, the field irrigation process's deep leakage and the surface run – off, raise the irrigation water usage, and reduce the volume of water extracted per unit of irrigation area.

(2) Biological water – saving measures: biological water – saving measures are to introduce, select and cultivate some drought – resistant crops and species that can endure arid environment. The function is to reduce the crop's transpiration so as to reduce the net consumption in the region.

(3) Agronomy water – saving measures: the agronomy technologies are important to enhance the use efficiency of farmland moisture. For example, the union utilization technology of a set of irrigation ways under inter – planting condition, the technology of coupling water with fertilizer and allocation application under the condition of different water – saving ways implemented, the technology of menu – typed combined water and agronomy measures under different inter – planting forms, the optimization and the improvement of cultivation measures and inter – planting condition.

Making full use of integrated benefits by set technologies, and reducing the water consumption during the crop's vegetal period and enhancing the output, the goals of saving water, high production, and high efficiency can be achieved finally.

(4) Exploitation of new water sources: it refers to the development and use of the inferior quality of water and rain water, such as the domestic sewage, industrial waste water, light salty water and so on.

(5) Management measures: It is usually divided into six categories: the improvement of irrigation system, the establishment of water – saving service system, the improvement of water source management, the reform of water management system, the policy, the laws and regulations, the formulation of a reasonable price standard and the charge ways of water fee and so on. The management measures are to gain a higher crop yield using the same moisture consumption through the enhancement of irrigation quality and the farmland moisture's production efficiency.

At present, the water – saving measures in the water – saving reconstruction of the irrigation area commonly used in our country mainly are: field supporting facilities, pipe irrigation, high and new technology (including spray irrigation, micro fills), electric – pump well construction, ditch reconstruction, planting structure adjustment and so on.

2.3 Water – saving principles

2.3.1 Ditch reconstruction

Ditch reconstruction is to reduce the loss in the water distribution process and to raise the channel water's usage, thus to achieve the water – saving goal through adjusting the ditch's layout, either canal lining or the establishment of anti – seepage protective layers, like concrete facing, rubble stone lining, plastic film and mixed material. See Fig. 5.

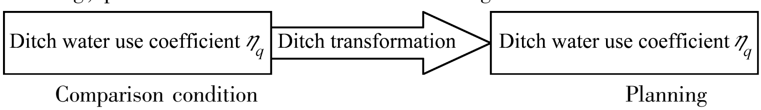


Fig. 5 Ditch transformation

2.3.2 Field supplement facilities

Field supplement facilities of water – saving measures mainly include supplement project, land leveling, and the change of big furrow to small and so on. Through the field supporting measures, the irrigation water loss can be reduced, the field water's efficiency can be enhanced, and the water consumption can be saved effectively. See Fig. 6.

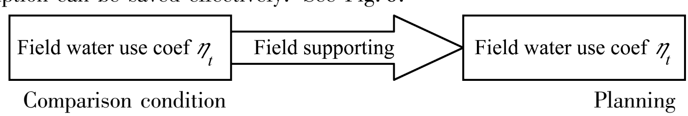


Fig. 6 Field supporting facilities

2.3.3 Pipe irrigation

The pipe irrigation measure is to replace the distribution channel with pipelines so that the water loss in the distribution process can be reduced, also the saving water goal can be achieved. See Fig. 7.

2.3.4 High – tech measures

The high and new technologies in water – saving mainly refer to the spray irrigation, micro fills and such like those. The water – saving quantity is produced through the change of canal irrigation to spray irrigation or micro fills and the enhancement of irrigation water usage and the reduction of irrigation quota. See Fig. 8.

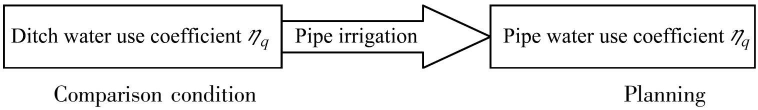


Fig. 7 Pipe irrigation

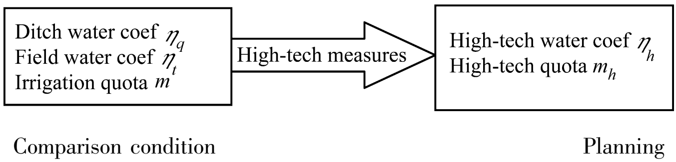


Fig. 8 High – tech measures

2.3.5 Electric – pump well construction

Electric – pump well construction achieves the goal of saving water through drilling new wells or reconstructing the old ones, replacing canal irrigation with well irrigation, increasing the ground water mining quantity, and reducing the channel water loss correspondingly. The water – saving quantity is composed of the decrease of dive evaporation because of groundwater exploitation and the decrease of water loss by diminishing the water transport length in canal. See Fig. 9. This paper only studied the water – saving quantity caused by the extraction of ground water to substitute channel water.

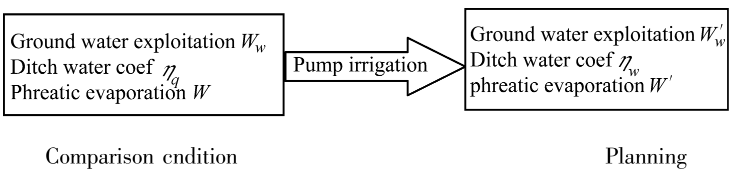


Fig. 9 Electric – pump well construction

2.3.6 Planting structure adjustment

The planting structure adjustment is to regulate crops' planting proportion in order to change the synthetical irrigation quota. To save water through the adjustment of planting structure is to reduce the farmland's synthesis irrigation quota under the condition of the constant irrigation area and irrigation quota, like compressing the high water – consumption crops' proportion and so on, thus to reduce the water consumption, and to achieve the water – saving goal. See Fig. 10.

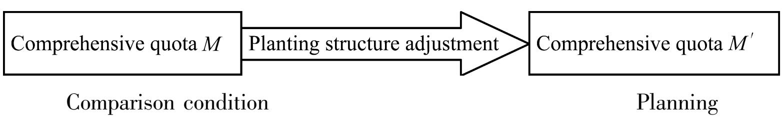


Fig. 10 Planting structure adjustment

3 Research on calculation method of water – saving quantity

3.1 Computation sequence

We can see from the chart of water demand process, during the irrigation process the water can be lost through four ways: the ditch's evaporation and leakage when being irrigated through ditches and wells, the pipe's leakage when being irrigated through pipelines and the field evaporation and leakage, which are related to the link's water volume. According to the water – saving principles of various measures, if the crop's irrigation area and quota are kept constant, the adjustment of planting structure will change the irrigation area's synthesis irrigation quota, then the irrigation area's net water demand will be changed, which will affect the water loss through field evaporation and leakage. The field supporting facilities will enhance the field water use coefficient and reduce the field evaporation and leakage. These two measures will cause the field's gross water demand to change. At the same time, the area increase of pipe irrigation, pump irrigation and high – tech water – saving measures also will cause the reduction of water volume transported through ditches. Thus it can be seen that, in the process of the irrigation area's comprehensive water – saving reconstruction the existed measures affect each other mutually. Therefore, the original state before reconstruction is not the all water – saving measures' comparison condition when we calculate the irrigation area's synthetical water – saving quantity, and each water – saving measure has its own comparison condition.

According to the water demand process and the different measure's water – saving principles, the influencing sequence of a single item in the irrigation area's comprehensive water – saving transformation will be: high – tech technology → planting structure adjustment → field supporting facilities → electric – pump well construction, pipe irrigation → ditch transformations.

3.2 Computation formulas

Water – saving quantity is defined as the water quantity reduced after water – saving measures were taken, the computation formula is:

$$\Delta W = W - W'$$

According to the definition of water – saving quantity, the calculation formulas of a single measure are as follows:

High – tech measure:

$$\Delta W_h = \frac{A_h \times M}{\eta_t \times \eta_q} - \frac{A_h \times M_h}{\eta_h}$$

Planting structure adjustment:

$$\Delta W_{planting} = \frac{(A - A_h) \times M}{\eta_t \times \eta_q} - \frac{(A - A_h) \times M'}{\eta_t \times \eta_q}$$

Field supporting facilities:

$$\Delta W_t = \frac{(A - A_h) \times M'}{\eta_t \times \eta_q} - \frac{(A - A_h) \times M'}{\eta_t' \times \eta_q}$$

Electromechanical pump construction:

$$\Delta W_w = \frac{A_w \times M'}{\eta_t' \times \eta_q} - \frac{A_w \times M'}{\eta_t' \times \eta_w}$$

Pipe irrigation:

$$\Delta W_p = \frac{A_p \times M'}{\eta_t' \times \eta_q} - \frac{A_p \times M'}{\eta_t' \times \eta_p}$$

Ditch transformations:

$$\Delta W_q = \frac{A_q \times M'}{\eta_t' \times \eta_q} - \frac{A_q \times M'}{\eta_t' \times \eta_q'}$$

in which, ΔW_q is the high – tech water – saving quantity; $\Delta W_{planting}$ is planting structure adjustment water – saving quantity; ΔW_t is field supporting transformation water – saving quantity; ΔW_w is electric – pump well construction water – saving quantity; ΔW_p is the pipe irrigation's water – saving quantity; ΔW_q is the ditch transformation water – saving quantity; M、M' respectively refers to the synthesis irrigation quota before and after the planting structure adjustment; M_h is the high – tech irrigation quota; A is the total irrigation area; A_q is the high – tech irrigation area; A_w is the pump irrigation area; A_h is the pipe irrigation area after transformations; A_q is the canal irrigation area after transformations; η_q、η'_q respectively refers to the canal water use coefficient before and after the ditch transformations; η_t、η'_t respectively refers to the canal water use coefficient before and after the field supporting transformations; η_w is the channel's water utilization factor; η_p is the pipe irrigation's water use coefficient; η_h is the high – tech irrigation water use coefficient.

4 Examples

A irrigation area has adopted the following water – saving measures in the water – saving reconstruction: adjustment of planting structure, canal lining, field supporting, increase of the irrigation area by well, pipe irrigation and high – tech irrigation. See Table 1.

Table 1 Statistical table of irrigation area's basic situation

Items		Before reconstruction	After reconstruction
Irrigation area (million mu)	Ditch	100.0	50.0
	Pump	0.0	10.0
	Pipe	0.0	20.0
	High – tech	0.0	20.0
Water use coefficient	Field	0.8	0.9
	Ditch	0.5	0.7
	Pump, canal	0.9	0.9
	Pipe	0.9	
	High – tech	0.85	
Comprehensive quota (m^3/mu)		230	195
High – tech quota (m^3/mu)		150	

The water – saving quantity using the overall computation method and sub – item computation method before and after reconstruction can be seen in Table 2.

Table 2 Computation chart of irrigation area's water – saving quantity (Unit: million m^3)

Items	Overall method	Sub – items	
		Before improvement	After improvement
High – tech		7,971	7,971
Planting structure adjustment		8,750	7,000
Field supporting		6,389	4,333
Pipe		6,389	3,852
Pump		2,556	1,926
Ditch transformation		8,214	6,190
Total	31,272	40,268	31,272

5 Conclusions

From the different computation results of different methods in Table 2, we can know:

(1) The sum of a single measure's water – saving quantity calculated using the sub – item computation method before improvement is bigger than the synthetical water – saving quantity, but

the calculation quantity after improvement equals to the synthetical water – saving quantity.

(2) The single measure's water – saving quantity calculated using the sub – item computation method before improvement is bigger than those after improvement, except the calculation result by the high – tech water – saving measures, which is kept the same. It is mainly because of the different comparison conditions used before and after the improvement. Before the improvement the comparison condition is the pre – reconstruction situation, but after the improvement the comparison condition is varying with the different single measure. Thus it can be seen, the selection of the comparison condition in the calculation of water – saving quantity is a key factor.

To sum up, the sub – item computation method before improvement does not consider the mutual influences between measures, so there are overlapping parts in the calculation, which cannot reflect the measure's real contribution to the comprehensive water – saving reconstruction. However, the comparison condition selected for every single measure in the sub – item method after improvement is different, and the mutual influences between measures are considered, so the calculated water – saving quantity can reflect the measure's real contribution to the comprehensive water – saving reconstruction and its computation method is reasonable.

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Group Decision Method of the Second Stage of Region Initial Water Rights Allocation and its Application Based on AHP

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Abstract: Initial water rights allocation is an important part in water rights allocation. It means water rights are allocated among different water users at the first time. It is a kind of benefit allocation and can be realized through market operation or other methods. However, the technical and economic feasibility of water rights allocation can't be realized just by one method. In this paper, a kind of water rights allocation model is proposed. AHP is applied and the opinions of different experts on water rights allocation are considered together in the model. Furthermore, the ability of the experts are also be evaluated in the model. Therefore, it is a scientific and practicable kind of method in reality. The results of an example are well – accepted, so this model can be widely used in regional water rights allocation.

Key words: initial water rights allocation, AHP (Analytical Hierarchy Process), expert – admitted degree, group decision

1 Initial water rights allocation

1.1 Initial water rights allocation

Initial water rights allocation is an important part in water rights allocation. It means water rights are allocated among different water users at the first time. There are three steps in the initial water rights allocation in basins. In the first step, water rights are allocated among different administration areas. In the second step, water rights are allocated among different industries in the same administration area. And in the last step, water rights are allocated to different water users. In the paper, the second step is studied in details.

1.2 Rearrange the preferential order of initial water rights allocation

The present preferential order of initial water rights allocation in China's Water Law is: domestic water, agriculture water, industry water, ecological environment water, shipping water. However, the order is not scientific because of the unspecific definition of domestic water rights, the improper order of ecological environment water and the loss of sewage discharge right. Therefore, the preferential order of initial water rights allocation is rearranged as: ensured water, basic condition water and high condition water. In each class, there should be domestic water, industry water, agriculture water and ecology water.

Ensured water should be allocated at first. In the total water supply to administration areas, the rest water can be allocated to basic condition water and high condition water after ensured water is allocated. Basic condition water allocation in the method of AHP is discussed in the paper.

2 AHP

AHP, the abbreviation of analytical hierarchy process, means that the relevant elements to decision are reclassified into objects, criteria and schemes which the quantitative and qualitative analysis are implemented based on. The characteristic of AHP is that the complex decision can be analyzed from the problems' nature, influential and relevant elements, and inner relationship using less quantity information. Water rights allocation is a multiple objective problem under the impacts of quantity and quality elements. So it is proper and scientific to allocate water rights in the method of AHP.

The steps are listed as follows:

The first step: to list the index system of basic condition water allocation;

The second step: to draw hierarchy structure chart (see Fig. 1):

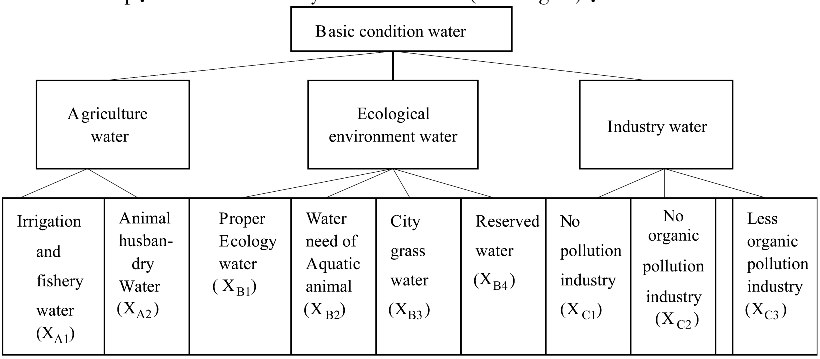

Fig. 1 Hierarchy structure chart of basic condition water rights allocation

The third step: to compute the relative important weights of the indexes.

(1) Judge matrix

Importance judge matrix $[a_{ij}]_{n\times n}$ is got through the importance comparison between every two indexes. The comparison criterion is Bipolar criterion, that is 1 to 9 critirion.

Table 1 Judging criterion of index importance

a_{ij}	1	3	5	7	9	2、4、6、8
i to j	Same important	Slightly important	Obviously important	Strongly important	Absolutely important	Important between each class

(2) To check compatibility

Compatibility index CI and random compatibility proportion CR should be calculated in the process of checking the compatibility of judge matrix.

$$CI = \frac{\lambda_{\max} - n}{n - 1}$$

$$CR = CI/RI$$

In the equations, RI is random compatibility index (see Table 2); CR is the ratio of random compatibility.

If $CR = CI/RI \leqslant 0.10$, judge matrix can be considered as compatible. Or else, judge matrix U should be adjusted until it is compatible.

Table 2 *RI*

n	3	4	5	6	7	8	9	10	11
RI	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51

(3) To calculate relative importance weight

In this stage, the important degree of each index should be defined. Calculate the maximum characteristic value $\lambda_{\max}$ of the judge matrix using Matlab, and the characteristic vector under $\lambda_{\max}$ is the important degree vector of each index $A = (a_1, a_2, \cdots, a_n)$.

3 Group decision and expert – admitted degree

In the process of group decision, each expert makes their own decision of a certain problem and then their opinions will be integrated in special ways. So the integrated process is a crucial step in group decision. There are two ways to integrate the opinions of all experts. One is to create integrated judge matrix from all the matrixes of each expert and to calculate water allocation weight. The other is to use AHP to calculate water allocation weight under each expert's matrix and then to synthesize the water allocation weight of each expert.

3.1 Methods of conforming integrated judge matrix

(1) Method of geometric mean

$A_k(a_{ij}^k)$ is the judge matrix of expert k, $A=(a_{ij})$ is the integrated judge matrix, $a_{ij}=\sum_{k=1}^{n}(a_{ij}^k)^{\lambda_k}$, $\sum_{k=1}^{n}\lambda_k=1$, n is the total number of experts, λ_k is the expert – admitted degree。

(2) Method of weighted arithmetic mean

$$a_{ij}=\sum_{k=1}^{n}\lambda_k\cdot a_{ij}^k$$

3.2 Integrating water allocation vectors of different experts

(1) Method of arithmetic mean: $w_i=\frac{1}{n}\sum_{k=1}^{n}w_{ki}$, n is the total number of experts, w_{ki} is the weighted value of expert k to sector i;

(2) Method of weighted geometric mean: $w_i=\prod_{i=1}^{n}w_{ki}^{\lambda}$;

(3) Method of weighted arithmetic mean: $w_i=\sum_{k=1}^{n}\lambda_k\cdot w_{ki}$ 。

3.3 Expert – admitted degree

Group decision by different experts is not only an evaluation of the importance of different water consuming sectors but also an evaluation of the ability of each expert. It is a kind of double evaluation problem. Expert – admitted degree is applied to evaluate the ability of each expert.

Fig. 2 is evaluation indexes of expert-admitted degree.

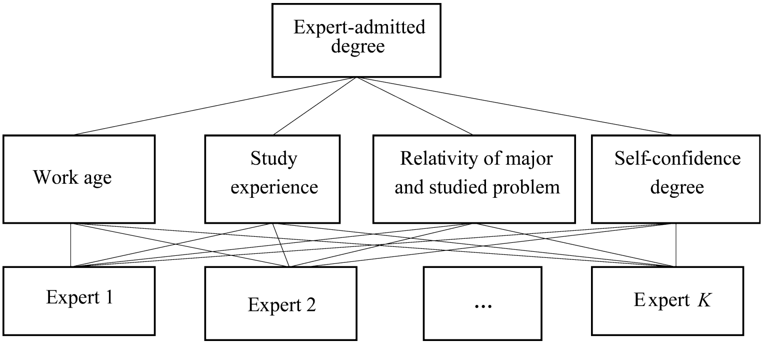

Fig. 2 Evaluation indexes of expert – admitted degree

In some papers, expert – admitted degree is called as expert – approved degree. It embodies the study experience, the relativity between the major of each expert and the studied problem, the ability and potential of each expert. In another word, it is the admitted degree of each expert by all experts (including himself or herself). The admitted degree of each expert is expressed in weights in group decision.

Quantify evaluation indexes of expert – admitted degree (see Table 3).

Table 3 Experts information quantified table

Work age (yr)	<5 (1)	[5,10) (3)	[10,15) (5)	[15,20) (7)	>20 (9)
Study experience	Doctor (9)	Master (7)	Bachelor (3)	Other (1)	
Relativity of major and studied problem	Same (9)	Relevant (5)	Different (1)		
Self – confidence degree	Evaluation of each expert to his or her own judge (%)				

Normalize the former three variables. If the larger the value is, the better the evaluation is,

$$r_j = \frac{x_j}{x_j^{\max}}.$$

If the smaller the value is, the better the evaluation is,

$$r_j = 1 - \frac{x_j}{x_j^{\max}}.$$

In the above equations, x_j is the evaluation value of index j, $x_j^{\max}$ is the maximum evaluation value of index j.

Calculate expert – admitted degree:

When calculating expert – admitted degree, the importance of four evaluation indexes is different, which means the weights of four indexes are different. The weights are given by the final decision maker based on their working experience and the reality of evaluation. The steps of calculating expert – admitted degree are as follows:

(1) Weights of four evaluation indexed are given as vector $[\alpha_i]$, $\sum_{i=1}^{4} \alpha_i = 1$;

(2) The normalized evaluation value of expert j to index i is c_i^j;

(3) The expert – admitted degree of expert j is: $s_j = \sum_{i=1}^{4} \alpha_i c_i^j, 0 < s_j < 1$.

4 Calculating steps of water allocation

The second method of integrating the opinions of different experts on importance of different water consuming sectors is applied in the paper.

The first step: to calculate expert – admitted degree of each expert in AHP and then normalize them;

The second step: each expert makes their own judge matrix of importance of different water consuming sectors $A_k(a_{ij})$ ($k = 1, \cdots, K$, K is the total number of experts), check the compatibility of A_k and calculate weights vector of importance of different water consuming sector w_k in AHP;

The third step: to calculate the weighted mean value of w_k using normalized expert – admitted degree and to get the importance weights vector w of different water consuming sector;

The fourth step: each item of w is multiplied by the according item of normalized water consuming vector of different sectors, get the water allocation vector, and then normalize it as ω;

The final step: ω is multiplied by the total water allocation amount, then water allocation amount to each water consuming sector is got.

5 Example

Assumption in the example: The total initial water amount is 10 billion m^3. There are A (agriculture), B (ecology), C (industry) users. A has two water users, B has four water users and C has three water users. The water consuming index vector of each water user is (41, 10, 15, 7, 10, 20, 31, 12, 8), the unit of which is m^3/hm^2. There are three experts who take part in the group decision of water allocation. The specific information of each expert is presented as Table 4.

The first step: to calculate expert – admitted degree of each expert in AHP and then to normalize them; the weights vector of the four indexed of experts evaluation is (0.1, 0.2, 0.2, 0.5).

Table 4 Specific information of experts **Unit: km**

	Work age (yr)	Study experience	Relativity of major and studied problem	Expert – admitted degreee
Expert 1	25(9)	Bachelor(3)	Same(9)	90%
Expert 2	11(5)	Master(7)	Relevant(5)	80%
Expert 3	5(3)	Doctor(9)	Relevant(5)	60%
Weight	0.1	0.2	0.2	0.5
Expert 1	1	3/9	1	0.82
Expert 2	5/9	7/9	5/9	0.72
Expert 3	3/9	1	5/9	0.60

Normalize the expert – admitted degree in the above table. The normalized expert – admitted degree of each expert is: $\overline{s_1}=0.38$, $\overline{s_2}=0.34$, $\overline{s_3}=0.28$.

The second step: each expert calculates water allocation weights vector w_k in AHP;

Table 5 Judge Matrix of expert 1 and compatibility check

θ	A	B	C	A	X_{A1}	X_{A2}	B	X_{B1}	X_{B2}	X_{B3}	X_{B4}	C	X_{C1}	X_{C2}	X_{C3}
A	1	7	7/2	X_{A1}	1	7	X_{B1}	1	7	5	9	X_{C1}	1	6	7
B	1/7	1	1/2	X_{A2}	1/7	1	X_{B2}	1/7	1	5/7	9/7	X_{C2}	1/6	1	7/6
C	2/7	2	1				X_{B3}	1/5	7/5	1	9/5	X_{C3}	1/7	6/7	1
							X_{B4}	1/9	7/9	5/9	1				
λ_{max}		3.0			2.0				4.0					3.0	
W_1		$(0.95\ 0.14\ 0.27)^T$			$(0.99\ 0.14)^T$				$(0.97\ 0.14\ 0.19\ 0.11)^T$					$(0.97\ 0.24\ 0.09)^T$	
CI		0			0				0					0	
CR		0			0				0					0	

Table 6 Hierarchy calculation results of expert 1

Criteria	A(0.7)		B(0.1)				C(0.2)		
Schemes	X_{A1} (0.88)	X_{A2} (0.12)	X_{B1} (0.69)	X_{B2} (0.1)	X_{B3} (0.13)	X_{B4} (0.08)	X_{C1} (0.75)	X_{C2} (0.18)	X_{C3} (0.07)
Weight	0.616	0.084	0.069	0.01	0.013	0.008	0.15	0.036	0.014

Expert 2 and expert 3 can calculate the water allocation weight vector in the same method.

Compatibility check: From the results of the three experts, CR of each A is less than 0.1, so the compatibility of judge matrix is satisfying. Or else, the compatibility of judge matrix should be improved. The improved method is talked about more in other articles.

The third step: to calculate the weighted mean value of w_k using normalized expert – admitted degree and to get the importance weights vector w of different water consuming sector;

Table 7 Integrating water allocation weights

$\bar{s}_k$	Water users	X_{A1}	X_{A2}	X_{B1}	X_{B2}	X_{B3}	X_{B4}	X_{C1}	X_{C2}	X_{C3}
0.38	W_1	0.616	0.084	0.069	0.01	0.013	0.008	0.15	0.036	0.014
0.34	W_2	0.43	0.07	0.036	0.009	0.018	0.036	0.312	0.052	0.036
0.28	W_3	0.16	0.04	0.14	0.12	0.09	0.05	0.152	0.032	0.018
w		0.43	0.07	0.08	0.04	0.04	0.03	0.21	0.04	0.02

The fourth step: the water consuming index vector of each water user is (41, 10, 15, 7, 10, 20, 31, 12, 8), so the normalized one is (0.273, 0.067, 0.100, 0.047, 0.067, 0.133, 0.18, 0.08, 0.053). Each item of the normalized water consuming index vector is multiplied by each item of w and the following vector is got: (0.118, 0.005, 0.008, 0.002, 0.003, 0.004, 0.038, 0.003, 0.001). Normalize it and ω = (0.65, 0.026, 0.044, 0.010, 0.015, 0.022, 0.209, 0.018, 0.006) is got.

The final step: ω is multiplied by the total water allocation amount, then water allocation amount to each water consuming sector is got.

Table 8 Results of water allocation **Unit: 0.1 billion m^3**

Water users	X_{A1}	X_{A2}	X_{B1}	X_{B2}	X_{B3}	X_{B4}	X_{C1}	X_{C2}	X_{C3}
Water amount	65	2.6	4.4	1	1.5	2.2	20.9	1.8	0.6

6 Conclusions and expectations

In this paper, the definition of initial water rights allocation is talked at first. Then AHP is used in group decision of water allocation. Expert – admitted degree is put forward to express the ability of different experts. A more scientific water allocation model, which integrates the different opinions of experts, is talked in this paper. However, the deficit is that the improvement of judge matrix has not been talked just because the compatibility of judge matrix is satisfying. In reality, it is an inevitable step to improve the compatibility.

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Water – saving Irrigation is the Basic Way to Expand the Yellow River Water Irrigated Area

—Citing as Xiaokaihe Irrigated Area of Shandong Province

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Abstract: Shandong Province is seriously lack of water resources and the Yellow River is its main guest water resource. The area along Shandong Yellow River is the main producing region of national high – quality grain. With the issue of a series of favourable policies for farms in recent years, the enthusiasm for peasants to plant grain has improved unprecedentedly, so the grain cultivated area is increasing constantly, and the demand for the water resource is enlarging. Whereas with the economic and social development of the provinces in the upper and middle reaches of the Yellow River basin, the water entering Shandong is reducing constantly. Therefore, the development of water – saving irrigation and the increase of the Yellow River irrigated area are basic ways to solve the shortage of water resource along Shandong Yellow River, also is the strategic choice to ensure the economic and social sustainable development, which is meaningful to alleviate the increasing gap between supply and demand of water resources. This paper takes Xiaokaihe irrigated area as an example to analyze and put forward some measures for agricultural water – saving irrigation.

Key words: the Yellow River irrigated area, water – saving irrigation

1 The background of the Yellow River irrigated areas of Shandong and Xiaokaihe irrigated area

1.1 The situation of the Yellow River irrigated areas of Shandong

Shandong Province is located in the downstream of the Yellow River, it is seriously lack of local water resources. The occupancy volume of water resource per capita and per acre is only 1/6 of the occupancy volume on average of nation. The Yellow River flows through 9 cities and 25 counties (urban area) in Shandong. It is the main guest water resource of Shandong Province. There are 58 irrigated areas along the Yellow River in Shandong Province, the design irrigated area is 40,324,000 acres and the design diversion ability is 2,424.6 m^3/s. Because the water resource of the Yellow River is in short supply, the effective irrigated area is 31,635,000 acres, account for 40% of total effective irrigated area in the whole province. According to the preliminary statistics, there are 4,427 km of channel in 58 irrigated areas in the province, among them 761.44 km channel is lining, with a lining rate of 17%; the branch channel is 12,963 km long, in which, 553.6 km is lining, with a lining rate of 4%. However, there are still 1,370,000 acres of cultivated land needed to be irrigated by the Yellow River, and the annual water consumption is about 230 million m^3.

1.2 The situation of agricultural irrigation water use

Shandong Province irrigated with the Yellow River begin in 1950s, with the Gross Nation Product and standard of living developing, the requirement of water from the Yellow River increased constantly. According to statistics, it was 1,330 million m^3 in average that the whole province diversion from the Yellow River every year in 1960s, 14,820 million m^3 in 1970s and 7,630 million m^3 in 1980s, although the Yellow River flow – breaking for years in the 1990s, the amount of annualdiversion still reached 7,290 million m^3, in which, the maximum diversion amount reached 12,340 million m^3 in 1989. The diversion water and the irrigated area of the Yellow River account for about 40% of total water consumption and total irrigated area in the whole province, the Yellow River water supply occupies a very important strategic position in the national economy in Shandong.

The composition of agriculture of the area along the Yellow River in Shandong Province is wheat, maize, cotton and vegetables. According to the research of the agricultural configuation and the requirement of water in the past five years, there are 24,572,000 acres of wheat, 18,845,000 acres of maize, 11,672,000 acres of cotton and 8,911,500 acres of vegetables planted every year. The area of wheat will reach 30,080,000 acres in 2006, which will take 60% of the total wheat cultivated area in the province. The periods needed water in the irrigated area are the spring irrigation from March to June, the autumn irrigation in September and the winter irrigation in December. The way to irrigate is mainly flooding irrigation method, and the water using coefficient is only about 0.45.

1.3 The basic situation of Xiaokaihe irrigated area

The Xiaokaihe intake gate was built up in November 1994, the design amount of diversion is 60 m^3/s. Xiaokaihe irrigated area water conservancy form a complete set completed in 1998 and run formally at the end of the year, the design irrigated area is 1,110,000 acres. At present, there are 1,234,000 acres irrigated area because a series of water – saving irrigation measures were taken. The benefit land area is 2,224,730 acres, including most of or all of the land of 667 villages and 23 towns in 6 counties of Huimin, Yangxin, Zhanhua, Wudi (county), with a population of 420,000 people involed. There are 91.5 kilometers of trunk canals in Xiaokaihe irrigated area, in which 51.3 kilometers canals is for transporting sand, 4.16 kilometers canals is for depositing sand and 36.04 kilometers canals is for transporting water.

2 The necessity of taking the water – saving measures in Yellow River irrigated area of Shandong Province

There are 68 counties of 11 municipals which are using the Yellow River water in Shandong at present. The mode of use grows from simple agricultural irrigation to multi – purpose water supply. Because the limited the Yellow River water resource can not meet the increasing need of industrial, agricultural production and domestic water, and the quoted is unorderedly, water cut – off frequently happened in the late 20th century. The first natural cut – off of the Yellow River happened in 1972, as the statistics show, in 28 years of 1972 ~ 1999, flow – breaking has appeared for 22 years at Lijin station, adding up to 1,091 days in 89 times, 50 days (average in year for flow – breaking) one year on average, it was 226 days flow – breaking in 1997.

Flow – breaking of the Yellow River has caused the enormous economic losses for industrial and agricultural production to Shandong. The losses are as follows: up to 2,220 million yuan in 1970s, 2,920 million yuan in 1980s, 35,140 million yuan in the 1990s (by the end of 1998). Especially In 1997, the direct economic losses of Shandong caused by flow – breaking is 13,500 million Yuan. Because of the cut – off and the aridity once – in – a – hundred – year, the aridity area along the Yellow River added up to 23 million acres, 16,000,000 acres ariditied serious, 7,500,000 acres ariditied destructive, the direct economic losses on agriculture are 7 billion yuan.

Since the integrated distribution of the Yellow River water in 1999, there have no cut – off for 7 years in succession, but because the water resource of the Yellow River is insufficient seriously, we adopt steps such as rotation irrigation, limiting discharge to avoid cut – off and exert the benefit fully in the peak period of irrigation, so much land has not enough irrigate or less times to irrigate. The agriculture irrigate water account 90% of the whole water diversion, and the utilization of the Yellow River water is about 45%, so the water – saving potentiality is enormous. It is necessary and probably to take water – saving irrigation by structural measures and non – structural measures. It is the basic way to solve the conflict of supply and demand, enlarge the irrigate area, increase the income of farmer along the Yellow River and the rational distribution of water resource.

3 The measures of water – saving of Xiaokaihe irrigated area

The irrigated area of Xiaokaihe has made an available attempt and explore, and have accumulated experience in reducing channel water loss and improving the management of irrigated area.

3.1 The measure of reducing water loss of channels by lining to avoid leakage and save water

The main measure on reducing water loss of channel in Xiaokaihe that reduces losses of water of channel is channel lining. In the early days of construction of Xiaokaihe, we completed 5 km whole – profile lining and 22.5 half – profile linling in the upstream. The accessorial projects were built up in Xiaokaihe in 2001, we completed 15.7 km channel bottom linling and 23.8 km half – profile linling. By now, all 51.3 km channel reaches the requirement of prevention of seepage. Channel of transfer of sand adopt big grade and long way technology of sanding, the depositing sand chamber lied in middle channel. It has achieved the aim of prevention of seepage, prevented frostbite, defended the pressure, defended eroding and defended deposit. Linling projects have changed the problem such as channel depositing seriously, sand breaking into farmland, life of irrigate area shortening, the environment deteriorating which caused by the fact that diversion in small flow for long time. It also achieve the silt – stable of channel, avoid land around channel be soiled in effect and advance the efficiency of water using. After the projects completed, the coefficient of water used of changed channel raised 0.24. The amount of water which used to irrigate one acre reduces greatly and the irrigated area increased greatly.

3.2 Improve the management level of irrigated areas to gain benefits

Because the investment on channel lining is great, it is difficult to solve by irrigated area itself, but government investment is limited after all, so the channel linling rate of majority of Shandong irrigated area of the Yellow River is still very low. Food and Agriculture Organization of the United Nations, World Irritate Committee and World Irrigate Academe have been studying for many years and consider that it has great water – saving potential by improving irrigation management withou much investment on the rebuilding of the current irrigation engnieerings.

By the improvement of irrigation management in Xiaokaihe irrigated area, irrigating quota are reduced to 272 m^3 from 351 m^3, with a water saving rate of 22%, the integrated water using coefficient is raised to 0.54 from 0.43. The measures are as follows.

3.2.1 Break the whole into parts and level up the land

The clear up of land can not merely improve the quality of irrigating, still save irrigation water, and can reduce the labour intensity while pouring water. Because it is long – way transfer of water and there is no ground water (groundwater is the salt water there) which can be usedin this irrigate area, so it is not suitable to take water – saving measures such as sprinkling irrigation, pipeline transport water, slight irrigation. Taking own situation into account, irrigated area adopts measures such as "big farmland is changed into little one, long farmland is changed into short one, wide farmland is changed into narrow one" and has achieved the purpose of the water – saving irrigation. Since 2002, all the villages and towns in the irrigated area have already finished the land clearing up and 490,000 acers canal – rebuild, effectively improved the useing coefficient of field water, changed the flooding irrigation, reduced the seepage loss, have realized effective water saving.

3.2.2 The water – saving pilot project and then enlarge gradually

Xiaokaihe irrigate area chose the district with good economic condition as a model water –

saving project. It chose Shejia Town of Wudi County as a pilot project, with an irrigation area of 40,900 acers and an investment of 10,654,000 Yuan. The project focuses on the whole profile channel lining and seepage prevent on the branch and main channel to make the. coefficient of field water using be raised to 0. 96 from 0. 85. At the same time, expending the project to larger area, making more people and organizations invest on it, to fan out to the whole irrigation area and finish the counstruction of the field engineering as soon as possible, offer a model for building up a water – saving irrigated area.

3.2.3 Automatical measurement of water and accurate calculation

Most of the irrigated area along the Yellow River in Shandong Province charge water in acre. It causes the flooding irrigation and repeated irrigation in the upstream channel, but only once irrigation or no water in the remote and high area in the downstream channel. So there is no water in the downstream but there is water wasted in the upstream Now Xiaokaihe irrigated area has already measured, calculated and charged water at the county level. Wudi County had charged water according to village since 2002. The other counties are also ready to do like this. Automatical measurement of water, accurate calculation and charging in cubic meter greatly enhance the consciousness of water – saving of farmers. The wrong ideas of "it is same to use much or less, it is a kind of waste without using water" have been changed. Therefore, the Yellow River water can be used in the remote and high area in the downstream channel. The measurement and calculation of water greatly promote water saving, reasonable distribution of water and the ecological balance in the irrigated area.

3.2.4 Regulation and management to save water

Xiaokaihe irrigated area leads the agricultural water – saving irrigation of the whole province. Its important content of management and objective of working is to build water – saving, ecotype and benefit type irrigated area. In the management system of irrigated area, water – saving is an important index in the evaluation of management. Irrigated area rationally draw and use water according to the assigned water index strictly. Report water – using plan on time every ten days, sign the water contract in time. Grasp the water using situation of irrigated area in time, rationally determine the flow discharge of diversion, scientifically allocate water in irrigated area. After finishing irrigating, close water diverting structure in time to avoid waste of water.

3.2.5 Adjust planting structure to save water

The planting structure are actively adjusted in this irrigated area by planting more drought – bear, water – saveing and high – yield crops such as cotton, Wudi date, Zhanhua winter date and so on. Statistical data shows that the planting area of cotton in this irrigated area reaches 43,000 hm^2 with a persentage of 60% of the total irrigated area. As a result, the water – save amout for one year can be up to 15,000 thousand m^3.

3.2.6 Use economic lever to save water by charging water

Based on the bearing capacity of the people in this irrigated area, according to the standard of water price of our country, the end price was rasied suitably aproved by the price management department. The end water price was improved from 0. 18 RMB to 0. 56 RMB at present. The water – saveing sense is initiated greatly by higher water price and charging water in cubic meter.

3.2.7 water and money saving by the management of association

The irrigated area explores the new irrigation management mode actively. The first water association, Zhiliu water using association, was established in September 2004. The serivced objects of Association have four administrative villages in Yangxin county, including 420 families, 1,829 population, 3,242 acres irrigated area. It mainly responsible for Zhiliu in an all – round way, operation, distribution, management, maintenance, water supply and the water charging.

In the early half year of 2005, Zhiliu water using association put into operation formally, the water charge was taken to the association of water directly by the irrigated area. Publish water charge, water price and water affair, broken the drawback of "water using together", each acre can economize water by 190 cubic meter. It has achieved the purpose which can economizes the water, distribute the water resource rationally. It lightenned peasant's water charge burden too at the same time, have reduced the dispute on the water charge, has promoted the construction of this harmonious society of area. At present, the irrigated area is improving the system, expand and establish more water households of association progressively to improve the enthusiasm of water – user sufficiently.

3.2.8 Propagandize to improve water – saving consciousness

Xiaokaihe irrigated area spends March 22 (World Water Day) developing the educational activity of economizing on water every year, for example, print the water – saving slogan, make sign board of water saving, propagandize the theme and basic situation of irrigated area. It has improved the consciousness of saving water of people. Water policy law enforcement group has been established at the same time, it offered law support to the system.

4 The main problems and suggestions of the Yellow River irrigated areas of Shandong

Because it serioiusly lacks of local water resource in Shandong Province, the conflict between supply and demand of water is still very outstanding. The water – saving potentiality is still enormous in the irrigated areas in Shandong Province, because the real water saving irrigation is no more than 10%. Therefore, it is meaningful to advance the water – saving irrigation not only for englarging the irrigation area, but also for the building of new rural area, the constructing of harmony society and the improving of the yield of agriculture. There are some recommendations to the problems about water saving irrigation in Shangdong Province are given as follows:

4.1 The irrigated area projects do not match each other and in bad repair

Most of the engineerings in the Shandong irrigated areas were built in 1970s. There were some drawbacks in the planning and design of the engineerings. They were built up in the base of old drainage projects and do not form a complete set. They were in bad repair, such as floodgate, bridge, containing and so on. Recommendation: Change the channel in a planned way: change main canal first, then branch canal to reduce water losses by channel lining.

4.2 The management level of irrigated areas is low

Firstly, the irrigated area project was not in unified measurement; Secondly, groundwater, surface water and the Yellow River water lack the overall planning in the irrigated area;. Thirdly, the facilities of measuring and calculating the quantity of water is insufficient. Finally, the field land is not flat, much water is wasted during flooding irrigation.

Recommendation: Through the water conservancy system reform of the irrigated area, advance the unified measurement of the engineerings in the irrigated area, strengthen the integrated management and distribution of the water resource; build field project construction well, flat the land, reduce the water consumption of each acre through the project transformation and improve the utilization ratio of the field water.

4.3 Insufficient non – structureal measures

The low water price cannot play a role in promoting water – saveing. Charging according to acre, the consumation of water is not direct related to the interests of peasants.

Recommendations: We should set up water price rationally according to the national regulation; well measure and calculate the quantity of water, charge according to cubic meter and distribute water by economic means.

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Water Supply Risk Assessment and Mode Optimizing of Water Saving Eco – city

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Abstract: To meet the demand of the Water saving eco – city planning, the author puts forward a new approachsing rainwater and urban lake water resource as the urban water supply, simulating and analyzing the risk index of multi – scenario with water supplying risk theory. Taking the water supplying mode optimizing of the Longzihu campus in eastern part of Zhengzhou City as a case study, the research shows that the water supplying mode should consider rainwater utilization, and the Longzihu lake should circulate with the lake of campus to reduce the cost of water supply, meet the demand of water saving and decrease the water contamination.
Key words: water supply, risk analysis, mode optimizing

1 Introduction

Much of the city area has high population density with heavy pressure of water supply in China. Meanwhile too much rainwater resource of the city discharges into the river with no utilization. In this condition, it will waste the rainwater resources, polluting the accepting water body. To meet the demand of the water saving eco – city planning, the author puts forward using rainwater and urban lake water resource as the urban water supply, whose advantages are to reduce the pollution in the rainwater transfer process, and accelerate the water circulation of urban lake. To ensure the safety of water supply, the author simulates and analyses the risk index of multi – scenario with water supplying risk theory, and optimizes the mode of water supply, it is useful for establishing reasonable urban water supply scheme, and resolving the lack of water resources and reducing the cost of water supply, and mainfaining healthy eco – environment.

2 Basic risk theory of water supply

The uncertain factors are the origin of the risk, the size of the risk lies on expectation and standard difference of the distribution of the loss probability. In the city area, if the water demand is larger than the water supply, it can lead to the water supply risk. Therefore, for assessing the risk of the water supply, the risk index should reflect the contradiction of water supply and water demand and the probability of danger, furthermore, it also should quantify ponderance of results to take some feasible measures to remedy. The risk index is established as follows:

2.1 Risk index and reliability index

Water supply system is commonly composed of water supply source and water supply establishments and water supply area. If water supply establishments are reliable and the water supply area is confirmed, the wreck of water supply system can be defined as the water supply sources can not satisfy the water demand, and cause the lack of water resouces.

Based on the theory of reliability, load is the drive of wreck for the system, and resistibility is the abilityof the system to counteract wreck . In the water supply system, Load (L) is the water demand number of the water supply district, Resistibility (R) is the ability of water supply system. If the state of the water supply system notes as:

$$F \in (L > R) \tag{1}$$

The natural state can be notes as:

$$S \in (L \leqslant R) \tag{2}$$

Therefore, the risk index of the water supply system is:

$$r = P\{L > R\} = P\{X_t \in F\} \tag{3}$$

where X_t is the state of water supply system at the period of time t. Accordingly, the reliability index of the water supply system is:

$$\alpha = P\{L \leqslant R\} = P\{X_t \in S\} = 1 - r \tag{4}$$

If there are long recordes of the work state of the water system, and reliability index can be defined as the ratio between the time of water supply and the total water supply period, viz.

$$\alpha = \frac{1}{NS} \sum_{t=1}^{NS} I_t \tag{5}$$

where, NS is the total time of the water supply; I_t is the state variable of the water supply system at the period of time t.

$$I_t = \begin{cases} 1, (\text{if no lack of water}; X_t \subset S) \\ 0, \quad (\text{if lack of water}; X_t \subset F) \end{cases} \tag{6}$$

2.2 Resistibility index

Resistibility index is used to describe the probability of the system return from the accident state to the order state, if the index number is higher; it indicates that the system can return to the order state more quickly. Therefore, it can be defined as following condition probability:

$$\beta = P\{X_t \in S | X_{t-1} \in F\} \tag{7}$$

By the formula of complete probability, it can be rewrite as:

$$\beta = \frac{P\{X_{t-1} \subset F, X_t \subset S\}}{P\{X_{t-1} \subset F\}} \tag{8}$$

Import integer variable:

$$Y_t = \begin{cases} 1, X_t \subset F \\ 0, X_t \subset S \end{cases} \tag{9}$$

and

$$Z_t = \begin{cases} 1, X_{t-1} \subset F, X_t \subset S \\ 0, \text{else} \end{cases} \tag{10}$$

Then

$$\beta = \frac{\sum_{t=1}^{NS} Z_t}{\sum_{t=1}^{NS} Y_t} \tag{11}$$

Order

$$T_{FS} = \sum_{t=1}^{NS} Z_t, \; T_F = \sum_{t=1}^{NS} Y_t \tag{12}$$

Then

$$\beta = \begin{cases} T_{FS}/T_F & T_F \neq 0 \\ 1 & T_F = 0 \end{cases} \tag{13}$$

In the formula (13), when $T_F = 0$, water supply system is working during the whole water supply period, and $\beta = 1$; when $T_{FS} = 0$, it indicates that the water supply system lies in the condition of water resources lack ($T_F = NS$), and $\beta = 0$. Generally speaking, when $0 \leqslant \beta \leqslant 1$, it indicates that water supply system can not satisfy the water demand sometimes, but it maybe supply water orderly again. If it is a long time for water lack, the resistibility probability is small, it is difficult for the water supply system working orderly again.

2.3 Vulnerability index

Vulnerability index is used to describe the degree of water resources lack for the water supply system. For quantifying measuring the vulnerability of the system, supposed the degree of lack of water is S_i at i times, the corresponding probability is P_i, then the vulnerability of the system can be expressed as:

$$\mu = E[s] = \sum_{t=1}^{NF} P_i S_i \tag{14}$$

where NF is the total times of the system water lack.

In the reliability analysis of the water supply system, the degree of damage for lack of water can be described as the quantity of lack of water resources. Supposed $P_1 = P_2 = ,\cdots, P_{NF} = 1/NF$, thus the frequency of lack of water resources for different quantity is equal, the formula (14) can be expressed as:

$$m = \frac{1}{NF} \mathring{a}_{t=1}^{NF} VE_i \tag{15}$$

Where VE_i is the quantity of lack of water for the *ith* time (m^3).

The formula (15) shows that the expectation of the quantity of lack of water can illustrate the vulnerability of water supply system. For eliminating the influence of different water demand, it can be expressed by use of relative value:

$$\mu = \frac{\sum_{i=1}^{NF} VE_i}{\sum_{i=1}^{NF} VD_i} \tag{16}$$

Where VD_i is the water demand at the period of lack of water for the *ith* time(m^3).

If $VE_i = VD_i$, then $\mu = 1$, it indicates that there is no water resources to provide, it lies in the easy damage condition; If $NF = 0$, then $VE_i = 0$ and $\mu = 0$, it indicates the water supply system is working orderly all the time. Generally speaking, $0 \leqslant \mu \leqslant 1$, during the definite period of water supply, if the quantity of lack of water resources is bigger, the system is more easy to damage, the degree of lack of water resources is more serious, it is accordant with the nature condition.

2.4 Risk coordination index

Coordination analysis mainly studies the relative variation process between water supply and water demand. Risk Coordination Index is used to reflect the risk coordination degreee between water resource supply and demand and to measure the degree of curve relative variation. It can be defined as:

$$H = \frac{1}{NS} \sum_{t=1}^{NF} \frac{\Delta_{max} - \Delta(t)}{\Delta_{max} - \Delta_{min}} \tag{17}$$

$$\Delta(t) = \left| \frac{NW_t}{\sum_{t=1}^{NF} W_t} - \frac{ND_t}{\sum_{t=1}^{NF} D_t} \right| \tag{18}$$

$$\Delta_{max} = \max(\Delta(1), \Delta(2), \cdots, \Delta(NS)) \tag{19}$$

$$\Delta_{mim} = \min(\Delta(1), \Delta(2), \cdots, \Delta(NS)) \tag{20}$$

where, W_t is the sequence of the water supply simulation; D_t is the sequence of the water demand simulation; NS is the total time for water supply.

If Risk Coordination Index H is bigger, the coordination between water supply and water demand is better. If $\Delta(1) = \Delta(2) = \cdots = \Delta(NS)$, then $H = 1$.

3 Case study

Longzihu area is an important part of the plan of new eastern part of Zhengzhou City, which is based on the construction of Longzihu eco – water system project, The eco – campus will include the lake and green grass belt, center island and campus town around the lake. According to the detailed plan, Longzihu lake lies in the center of this area, the shape of lake is a circle, the area is about 1.2 km^2, the campus town is designed d like a sector around the lake, and there is a lake in each campus, the total area is 0.33 km^2, the research center and public establishment is located in the center island. Due to high population density and lack of water resources in the district in the future, it is necessary to establish the water supply plan reasonably to reduce the cost of water supply and the demand of water saving and decrease the water contamination.

Longzihu lake and the lakes in the campus are used as the scene and entertainment lake, the water quality requires Ⅳ, If this water resources is used as the source of water supply, mainly as no drink water such as daily life washing and road watering. Considering Zhengzhou is a water resources lack city, the rainwater should be used as water supply. Therefore, the water supply plan is classified into two categories, one is rainwater utilization plan, and another one is no rainwater utilization plan. According to the running condition of Longzihu Lake and lakes on campus, four scenarios are presented to simulate their characteristic:

Scenario A: The lakes on campus are a part of source of water supply; Longhu lake discharge is distributed in 3 phases: 60% of water is discharged from June to July, August to September, 30% of water resources is discharged from April to May, October to November, the other month is 10%.

Scenario B: The lakes on campus are a part of source of water supply; the discharge course of Longhu is optimized by water demand course of Longzihu and campus district.

Scenario C: The lakes on campus are not source of water supply, the lake is circled by oneself. Longhun lake discharge is distributed in 3 phase: 60% of water is discharged from June to July, August to September, 30% of water is discharged from April to May, October and November, the other month is 10%.

Scenario D: The lakes on campus are not the source of water supply, the lake is circled by oneself. The discharge course of Longhu is optimized by water demand course of Longzihu and campus district. According to forecast of water supply and water demand on the campus district in 2030, calculating the water supply risk index by water supplying risk theory, the result is shown in the Table 1.

Table 1 Result analysis of water supply risk index on campus in 2030

Scheme	Rainwater utilization on campus				No rainwater utilization on campus			
	Scenario A	Scenario B	Scenario C	Scenario D	Scenario A	Scenario B	Scenario C	Scenario D
Risk index	0.12	0.00	0.63	0.06	0.36	0.00	0.77	0.19
Reliability index	0.88	1.00	0.37	0.94	0.64	1.00	0.23	0.81
Resistibility index	0.68	1.00	0.13	0.93	0.36	1.00	0.12	0.50
Vulnerability index	0.21	0.00	0.21	0.35	0.27	0.00	0.24	0.45
Risk coordination index	0.67	1.00	0.40	0.82	0.55	1.00	0.28	0.64

4 Results analysis and mode optimizing

(1) According to the result in Table 1 for scenario A, C and D the risk of water shortage in Longzihu lake and campus district is great so the reliabilities are very low, especially for scenario C,

the risk index is 0.63, risk coordination index is 0.40.

(2) If rainwater utilization, is not considered in scenario B, water supply can be satisfied, there is no risk for water supply; but if considering rainwater utilization, and comparing water supply risk at scenario A , C and D with scenario B, each index is much better than scenario B, which indicates that rainwater utilization can mitigate the pressure of water supply obviously.

(3) Comparing scenario A and C with scenario B and D, it can illustrate that if the lakes on campus and Longzihu lake are the source of water supply, it can mitigate the loss of lack of water and reduce the risk, enhancing coordination between water supply and demand.

Therefore, the mode of water supply should consider rainwater utilization, and the discharge process of water distribution of Longhu lake is optimized by water demand process of Longzihu lake and campus district.

5 Conclusions

The paper analyzes the risk index (risk index and reliability index, resistibility index, vulnerability index, and risk coordination index) and simulates multi – scenario water supply with water supplying risk theory. Taking the water supplying mode optimizing of the Longzihu campus district in eastern part of Zhengzhou City as an case, the research shows that the water supplying mode should consider rainwater utilization, and the Longzihu lake should circulate with the lake of campus to reduce the cost of water supply and the demand of water saving and decrease the water contamination.

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Research on Water Saving Irrigation Schedule under Agro – water – saving and No – full Irrigation in Inner River Basin

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Abstract: There were many studies on agro – water – saving technique and no – full irrigation at domestic and foreign. However, the study on association of the two water saving technique was seldom done. In this research, the wheat and maize should be the objects. The water transmission of soil to atmosphere and leaf to atmosphere would be important parts in this study. Meanwhile, calculation method of soil factor under the mulching condition and arid index will be another research objects. Irrigation schedule under agro – water saving and no – full irrigation will be made too. Through the study, it will provide the theoretic support and available water saving techniques to solve water shortage problem in the inner river basin of China.

Key words: agro – water – saving technique, no – full irrigation, water saving irrigation schedule

Water resource on agricultural irrigation takes about 73% in the whole water resource consumption in China in 2003. In recent years, this amount has increased gradually with population growth. Agricultural irrigation plays an important role in guarantying food security. Chinese population would get to 16.0 hundred million in 2030, and food demanded would be up to about 7.2 hundred million ton at that time. And irrigated area would be 6.0 hundred million hectare to meet the food demand. In addition, the need of agricultural water resource would increase from 4,000 hundred million cubic meters to 6,650 hundred million cubic meters. Therefore, so high water resource supply could not reach at the present situation of water using model. Agricultural sustainable development must base on 4,000 hundred million m^3 water resource. The very way of solving the water shortage problem is to develop water saving irrigation. Irrigation scheduling is an indispensable process to realize agricultural water saving irrigation. The study would put forward a feasible irrigation scheduling to inner river basin under agro – water saving and no – full irrigation. It will be an economical and practical way to resolve water resource crisis in Chinese inner river basin, and it also has a certain reference value to arid agricultural irrigation. Down reach is arid region, its annual precipitation is 150 mm to 250 mm and evaporation 800 mm to 1,800 mm.

1 General situation of research area

The research area is Shi Yang River basin which is well known as water shortage and serious water resource crisis. Shi Yang River basin locates at the east of Hexi corridor with area of 4.1×10^4 km^2. The upper reach is the water source of Shi Yang River which is at Qilian mountain. The annual precipitation is 500 mm to 700 mm, and annual evaporation is about 800 mm. The water resources characteristic is the surface water and the ground water has extremely closely, forming the unified water resources system. It can be seen from some material (Xu, 2003) that irrigation area is about 2.9×10^5 hm^2, and the population is up to 2.23×10^6. The gross water using efficiency is 154%, and the net using efficiency is higher than 95%. All those index are very higher than rational efficiency accepted by international. According to local water department forecast (Zhang, 1995) that there would be still -7.03×10^8 m^3 water shortages at 2010 even if some normal water saving methods and water shift engineering were put into practice.

2 Research status on agro – water saving and no – full irrigation

Agro – water saving is one of field water saving irrigation methods. It includes tillage, mulching, chemistry controlling and so on. The mulching still becomes more and more popular for its economical and feasible. Straw mulching and film covering are two methods in this agro – water saving technology. Straw mulching is welcome in the recent years because this type of water saving is good at controlling weed, adjusting micro – climate and low consumption and so on(Zhou,1997; et al., Jacob 1996; Tolk, 1999; Gonzalez et al., 2001). Different from normal tillage, straw mulching changes surface soil condition, and affects soil evaporation. Soil temperature in spring has direct effect to germination of seed. Straw mulching reduces soil temperature and has negative role on crop growth in the spring(Jing et al.,2006). In the study of hydro – thermal coupling, the research would attach importance on mulching layer and hydro – thermal change in straw mulching (Li et al.,2000). Fan Xiangyang(Fang et al.,2002) has studied the straw mulching in Xiaohe irrigation region and found that straw would save water and conserve soil moisture. The research also indicated that straw mulching not only restrainsed soil evaporation but also improved field micro – temperature. Zhou lingyun (Zhou,1997) has had a trial in Fengqiu, and found that soil water content in 0 to 50 cm had increased 4.2% than normal tillage, and it also had an active part in crop growth. Straw mulching Gao zhiqiang(Gao,1999) studied on straw mulching with 5 years in Shanxi province, he found that straw mulching was the best water saving method than film covering, deep furrow and normal tillage. Huang Yilong and his partner(Huang et al.,2004) have made straw mulching study within 13 years. They found that not only in wet year but arid years, straw mulching could improve crop output. Film cover is regarded the most breakthrough in wheat planting(Yang et al;,1997;Pepler et al.,2005), and it has an obvious water saving effect. In Hexin corridor of China, film cover is a popular tillage, besides in wheat, it also in maize and cotton. Many researches showed that film cover decreased water consumption, adjusted soil temperature, controlled wed and improved the output.

No – full irrigation was put forward basing on full – irrigation. Crop water demand is met at anytime in crop growth. However, no – full irrigation does not always meet crop need, in some stages of growing period, field is irrigated not attaching the point which would be done in full – irrigation(Wang, 2003). Because the method doses not reduce the output and water shortage becomes a worldwide problem, it becomes more popular. In theoretic study on no – full irrigation, many scientists had completed many aspects such as evaporation, water requirement, water production function and so on. Besides, many models on no – full irrigation had been built up.

3 Water saving irrigation scheduling under agro – water saving and no – full irrigation

Generally speaking, water saving irrigation is an efficient water resource allocation in crop growth period, which base on different output to different water shortage stage and find out an increase production in the whole growth period. It is said that water quota, irrigation degree, irrigation date and soil water content should be allocated with optimization methods under limited water resource controlling. It should be pointed out that the optimal strategy is the whole effect got to an optimal one but not every stage.

Research of water saving irrigation scheduling should be implemented to different crops in arid region. Splitting design will be selected as the trial design, the main treatment is agro – water saving with the straw mulching and film covering two levels, and vice treatment is no – full irrigation with 2 to 4 levels according to crop growth and controlling index would be soil water content comparing with field water capacity. There are 3 times of repeation.

It would study the following aspects:

(1) Study on storage irrigation in arid region under agro – water – saving. The controlling objects would be soil water in the next spring and storage irrigation quota. Through the study, it would give a reasonable program which reduce or cancel storage irrigation quota.

(2) Water transmition at the interface between soil and atmosphere. Study on water flux at the interface between soil and atmosphere, and research at evaporation under mulching condition; know about soil water movement under mulching and no – full irrigation; analyze calculation method of soil factor with its variety character.

(3) Pore action at the interface between leaf and atmosphere. Study the relationship of photosynthesis, transpiration and pore conduction under agro – water – saving and no – full irrigation. Analyze the effect factor on water transmition and crop factor changing character under the field microclimate.

(4) Crop – water production function model. Study rational relation between crop and water under the condition of agro – water – saving and no – full irrigation; study the model of Jensen at the trial situation and seek the sensitivity index.

(5) Irrigation schedule of the main crop. Constitute the water saving irrigation schedule under agro – water – saving and no – full irrigation with the method of DP. Compare the reality of irrigation region to check it's feasibility in the region.

4 Prospective results

According to the field experiment and theoretic analysis, the study would get the following objects:

(1) Ascertain optimal storage irrigation quota under agro – water – saving technique in the inner river basin with the aim at requirement of spring soil water and water evaporation in the last winter. Explore feasibility of reducing or canceling storage irrigation.

(2) Set up a soil water movement model under agro – water – saving and no – full irrigation; seek a better formulation of computing ET0; bring forward a better method of soil factor under agro – water – saving techniques and its changing regulation under the micro – climate.

(3) Ascertain relation of photosynthesis, transpiration and pore conduction under agro – water – saving and no – full irrigation; seek for critical water consumption on photosynthesis production; set down quantitative connection between soil water stress and crop physiological character.

(4) Establish a water – crop production model and ascertain a value of water sensitivity index of inner river basin. And irrigation water resource collation program would be built up in the period of crop growth. Meanwhile, a domain effect at a larger scale would be studied in the inner river basin.

5 Conclusions

Water saving irrigation is the inevitable choice of sustainable development of Chinese agriculture, the formulation of water saving irrigation scheduling is the base job in order to realizing water saving irrigation of agriculture. Studies suggest whether agro – water saving or no – full irrigation, they both have a good effect on increasing production of water saving. The research on combining the both shall be allocated, and the more effective water saving irrigation scheduling needs exploring. Because mulching method has the effect of inhibiting available soil water in agro – water saving, no – full irrigation can decrease irrigating water quota. The research on combining the both will decrease the times of irrigation and irrigation quota. On the premise of ensuring the number of crop product, the research decreases the irrigation quota. The result of research can promote in arid regions and semiarid regions, too.

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Benefit Analysis on Continuous Construction of Water Saving Innovation Projects in Baojixia Irrigation Area

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Abstract: During eight years from 1998 to 2005, China had carried out continuous construction of main and branch irrigation channels and related buildings, as well as water – saving innovation projects in Baojixia Irrigation Area stage by stage. Along with the completion and operation of these annual new projects, the appearance of irrigation constructions had been improved obviously to a certain extent, which has gradually present the benefits on engineering disaster – reducing, economy, water – saving and ecological aspect. Based on tracing investigation and operation tests, it show that projects' maintenance fees and accidents compensation have step down, food yield has increased gradually; water irrigation efficiency and water – saving amounts has rise continuously, furthermore, ecological environment has been improved. Therefore, to a certain extent, water shortage in the irrigation area has been mitigated; consequently, rural economic development has been speed up in the irrigation area rapidly and sustainably.

Key words: continuous construction compatibility, water – saving reconstruction project, benefit, analysis

Baojixia Irrigation Area of Shaanxi Province is composed of Weihuiqu irrigation area, Weigaochou irrigation area and Baojixia Irrigation Area, each of which was established in 1937, 1958 and 1971 separately. This area is the biggest irrigation area and food production foundation at present in Shaanxi Province which irrigates 194,400 hm^2 farmland of four cities (area), such as Bao Ji City, Yang Ling City, Xian Yang City and Xi'an City, 14 counties (city, area), 97 towns, therefore, it is called "the biggest granary". Because of the low quality of engineering construction, long – time operation and lack of funding, the area's channels lining rate is low and irrigating facilities' damages are severe due to aging. Since listed in the continuous building and complete set project and the water saving reformation project in 1998, the irrigation area had regarded water – saving as concentration, emphasized on channels lining, had reformed 11channels extended to 58.15 kilometers, 200 buildings, 2 pump stations and 2 dangerous segments. In all, the investment amounted to 102.27 million yuan from 1998 to 2005.

As these projects put into effect, the appearances of the area had been improved to a certain extent, and benefits appeared step by step. After tracking survey and operation testing to every project, water – using efficiency improved, and water – saving amounts notably increased. The results showed that these projects ameliorated water shortage to the certain degree, strengthened the development of rural economic in the area. Combining with the irrigation area's reforming practice, the projects' benefits will be analyses from five aspects.

1 Disaster – reducing benefit

Baojixia Irrigation Area was assessed as the first level senescent area in 1992, when conducted aging investigation in large – scale irrigation areas in China. Because of serious siltation, damages, and long – time running, especially large amounts of soil channels, it's normal that the water – flowing capacity is insufficient, and at the same time accidents often occurs, such as leakage, overflowing and bursting. Since water – saving reformation projects put into effect in 1998, the irrigation area had reformed channels 58.15 kilometers long , 200 buildings (herein Weishui siphon and Qishuihe aqueduct), and the channel lining rate improved 5% , lining intact rate improved

10% . As these projects put into practice, not only having eliminated the potential risk, reduced the rate of accident occurrence, but also decreased the projects, maintenance fees and accidents compensation. Compared with 1997, it the projects, maintenance fee was cut down 1.325,4 million Yuan with 72.8% declining rate, accidents compensation was cut down 6.49 million Yuan annually (details see Table 1). Besides, decline of the potential troubles and dangerous circumstance promote the safety coefficient of water transferring and irrigation guarantee rate in the lower reaches. Up to 2005, annual drought loss in the irrigation area declined from 120.16 million Yuan to 51.75 million Yuan, with 56.9% declining rate.

Take Weishui siphon the biggest irrigation building as example, which can control irrigation area of 1.06 million hm^2, it will lead to serious loss if the building is broken. If crop yield reduces 340 kg each Mu per year (just considering cereals, multiple – planting index is 1.65), crop yield will reduce 578 million kg in the total irrigation area. Take the cereals price as 1.0 Yuan/kg, hydraulic dispensing coefficient as 0.4, then the area's annual direct economic loss will amount to 231 million Yuan, but the indirect loss can't be evaluated. Since the building was innovated, the safe water – flowing coefficient has enhanced apparently, and the drought – happening frequencies have decreased.

2 Economic benefits

After executing water – saving reconstruction project, it had added water – flowing capability 9.4 m^3/s, timely water volume 23.933 million m^3, improved irrigation area 10.8 thousand hm^2, recovered irrigation area 2,660 hm^2, annually increased crop yields 42.5 thousand tons (details see Table 2). The area's multiple – planting index had ascended from 155% to 166%, plant structure optimized continuously, and the proportion of food products and economic products adjusted from 8.2:1.8 to 7.3:2.7. In 2005, wheat, corn and fruit yield achieved to 385 kg, 441 kg and 2,911 kg, compared with 1997, increased 25.8%, 41.9% and 58.1% respectively, and water – producing capacity reached to 1.89 kg/m^3 in beneficial area.

Along with irrigation facilities improved continuously and agriculture plant assured, many peasants in the irrigation area began to develop transport, greenhouse vegetables and other economic undertaking, established basic for rural economic structure adjustment. As statistics, the peasants' average net income has increased from 1,460 Yuan in 1998 to 1,908 Yuan, increasing rate 31%. As the consumption level enhanced, the rural economy walked to prosperity, and society discipline grew better. So water – saving reconstruction not only has accelerated irrigation area development, but also boosted the local economic development, promoted the spirit civilization construction, as well as helped to construct the socialism new countryside.

3 Water – saving benefits

The area's channel system extends long. Before reconstruction, due to soil channel leakage and irrigation facilities incompatibility, as well as irrigation techniques out – to – date, the area's water – usage coefficient always lingered below 0.50. After implementation of water – saving reconstruction project, 58.15 km long main channels which severely affected water – flowing had been gradually reconstructed. As actual measurement, the channels' water – usage coefficient averagely increased approximate 4 percentage, relieved water loss 12.9 million m^3 (details see Table 3) every year. At the same time, cooperating with farm water – saving project and "three improvement and two all" irrigating technique, the area's irrigating water – usage coefficient have increased to 0.532 from 0.50 in 1998, increasing rate 3.2%. According to the multi – year channels' average water – input, the area's water – saving capacity is 19.2 million m^3 large annually. Furthermore, the irrigation cycle shortens from 23 days to 21 days, shortening ratio 8.7%.

Table 2 Economic benefits analysis on water – saving reconstruction projects in the irrigation area

	Project name	Adding water – flowing capacity(m^3/s)	Adding water volume timely (ten thousand m^3)	Recovery irrigation area (hm^2)	Improved irrigation area (hm^2)	Increased crop yields (ten thousand tons)
1	Main channel reconstruction	1	345.60		1,333	0.42
2	North channel reconstruction	2	691.20	773	2,867	1.15
3	East channel reconstruction	0.6	103.70		733	0.23
4	North channel Pangjia segment excluding risk				200	0.06
5	The second branch of main channel reconstruction	1.0	216.00	467	1,000	0.46
6	The third branch of main channel reconstruction	0.6	129.60	200	400	0.19
7	The eighth branch channel of main reconstruction	0.9	194.40	220	600	0.26
8	The second Beichang branch channel reconstruction	0.6	129.60	133	733	0.27
9	The first branch of east main channel reconstruction	0.8	172.80	267	900	0.37
10	The fifth branch of east main channel reconstruction	0.7	151.20	133	733	0.27
11	The sixth branch of east main channel reconstruction	0.5	108.00	267	800	0.34
12	The Emperor conveying water channel reconstruction	0.7	151.20	200	533	0.23
	Total	9.4	2,393.30	2,660	10,833	4.25

Table 3 Increase of channels' usage coefficient after the completion of water – saving reconstruction projects in the irrigation area

	Project name	Before reconstruction	After reconstruction	Increased percentage	Annual decreased water loss (ten thousand m^3)
1	Main channel reconstruction	0.90	0.92	2	107
2	North channel reconstruction	0.75	0.83	8	407
3	East channel reconstruction	0.91	0.93	2	97
4	Weishui siphon excluding risk	0.92	0.93	1	20
5	Qishuihe aqueduct consolidation	0.91	0.92	1	135
6	South Shangzhuo pump reconstruction	0.70	0.84	14	9
7	North channel Pangjia segment excluding risk	0.80	0.85	5	22
8	The second branch channel of main reconstruction	0.71	0.87	16	120
9	The third branch of main channel reconstruction	0.82	0.84	2	36
10	The eighth branch of main channel reconstruction	0.82	0.85	3	46
11	The second Beichang branch channel reconstruction	0.82	0.84	2	41
12	The first branch of east main channel reconstruction	0.82	0.83	1	27
13	The fifth branch of east main channel reconstruction	0.82	0.87	5	116
14	The sixth branch of east main channel reconstruction	0.82	0.85	3	79
15	The Emperor conveying water channel reconstruction	0.82	0.84	2	27
	Total	12.34	13.01	3.94	1,290

4 Ecological benefits

Baojixia irrigation area is a large scale area which abstracts water from Weihe River. Since 90's, water resource in the Weihe River's decreases sharply, which result in water shortage periodically and frequent drought. Furthermore, one third of the area is irrigated by channels and wells. Affected by project aging, weak facility, fitting rate, lower irrigation assurance and other factors, many peasants abandon channels irrigation facility, instead, just depend on wells, which leads to imbalance between water abstraction and supplement and descent of groundwater level seriously in some counties in irrigation area. As the implementation of water – saving reconstruction project's, not only changed regional water resources supply condition, enhanced water utilization, recovered parts of channels' irrigating areas, but also restricted the phenomena that the groundwater level decreased each year, greatly relieved groundwater exploiting unduly and water resources shortage. According to recent three years actual data, the area's groundwater deterioration has been radically controlled, the groundwater level trends to stable, and the whole condition evolves to "channel well combination, support well via channel, and complementary water to channel via well, reserve abundant water for exhausted water season". Along with projects, irrigation administration has harnessed ecology environment deeply and achieved striking accomplishment. Up to end of 2005, the area's farm forests amount to 17,700 hm^2, saving groundwater 27.08 million m^3, decreasing groundwater exploitation rate 11.19%. Ecological water consumption increase to 310.07 million m^3 from 240.3 million m^3 in 2000, increasing rate 22.5% compared with 95's, effectively improved the area's ecology environment.

5 Other benefits

Before 1998, due to parts of main channels short of water – flowing assurance, the sub – channels' reconstruction failed to apply. After water – saving reconstruction execution, the situation thoroughly changed. As the leakage loss decreases and irrigation assurance enhances, it creates excellent basic for sub – channels reconstruction. At the same time the area carefully carried out hydraulic industrial policy and provincial "two decision" outline, steadily boosted "main channel special administration, branch channel multiple – mechanism, peasants manage sub – channel, personnel involvement" as the stem, stock cooperation and peasants water consumption committee as the main types to reform radical level management mechanism. The peasants joined in irrigation administration system reformation with progressive passion, took active part in putting forward application to administration, required lease and contract sub – channel. Up to end of 2006, 1,427 sub – channels had been reconstructed: 32 peasants water consumption committees, reconstructed 457sub – channels; 37 water supply community, reconstructed 756 sub – channels; 193 sub – channels in contact pattern; 21 sub – channels in lease. Beside these, There were 35 branch channels reconstructed in which 22 branch channels were whole reconstructed. After all, there were 229,500 families involved, 120,000 hm^2 area controlled which occupied 72.8% of the effective irrigated area. In all these, there was 633.3 hm^2 area restored, 1.819 million society capital collected, 459.3 km channels and 12,880 buildings reconstructed, 1,079 peasants and 193 administrators involved.

With the help of these reconstruction patterns, advantages were embodied on engineering maintenance and water fee and so on. First there were people and supporting money responsible for final channels and maintenance; second medium management procedures were decreased and water fee was saved; third along with operators' incomes increased, maintenance enthusiasm enhanced, administrant coherence was centered; forth special irrigating team served to family which made peasants convenient and relaxed to irrigation. Hence water – saving reconstruction not only promotes irrigation facilities' condition, but also reaches such effectiveness: reconstruction boosts innovation, innovation promotes development.

6 Conclusions

Since 1998, China has invested certain capitals on Baojixia irrigation area's water – saving projects. The area has obtained step – by – step improvements on channels lining, lining intact and dangerous segment declining rate etc. Because of being constructed earlier and historical finance in arrears, the area still needs further enhancement in channels lining and lining intact. A lot of issues still disturb the area such as dangerous segments, serious siltation and old buildings etc. At present, lining rate of channel in irrigation area only reaches to 58%, lining intact rate is 77.9%, building intact rate is only 70% and dangerous segments occupy 18% of total main channel.

In terms of the area's water – saving layout and current status, there are a lot of problems need to reconstruct such as 615.504 km main channels, 1,537 buildings, 207.701 km dangerous segments, 15 slide bodies across 98 km belt, and 7 pumps. In order to exert more contribution to construct the rich society and socialism new country, the irrigation area should continue to strive for more water – saving reconstruction investment to further enhancement of the area's service functions.

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Effect of Water Right Tranfer in Ningmeng Irrigation Area

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Abstract: Water shortage has been an important factor to restricting our economic society development. The basic settlements are establishing water saving and pollution prevention society, implementing water resources optimized distribution and boosting water resouces use efficiency. In the Ningmeng irrigation area water resources are very scarce and needed Wate right transfer is the approach that boosts the water use efficiency of industry and agriculture. By means of water resources use right transfer is regulated, and water resources optimized distribution, use efficiency, thrift and protection in the Ningmeng irrigation area boosted. It would also make an effect on environment and the Yellow River runoff of the irrigation and neighborhood area. Therefore, it should be done to ascertain appropriate water right transfer scope and estimate the water quantity for transfer rationally.

Key words: Ningmeng irrigation area, water right transfer, effect

Water is basal natural resource and also an econuomic resource. It is not only the lifeline of human existence but also the important substantial fondation of sustainable development society. Water shortage has been an important factor to restrict our economic society development. The basic settlements are constituting water saving and pollution preventing society, implementing water resources optimized distribution and boosting water resouces use efficiency under the instruction of central water policy and new water – control thoughts. Some regions have carried out water right transfer in succession, regulated water resources use right transfer and boosted water resources optimized distribution, use efficiency, thrift and protection over the years. As the experimental unit of water transfer, Ningmeng irrigation area started in 4 th, 2003 in the Yellow River Basin. There have been 5 items approved at present.

1 Ningmeng irrigation area general. description

Nngmeng irrigation area contains the irrigated regions in Ningxia Province and west of Inner Mongolias Province that are irrigated by the water of Yellow River mainly. Ningmeng irrigation area is the continental climate, dry and little rain, vast evaporation, aboundant sunshine, big difference in temperature between day and night, plentiful quantity of heat, long frost – free period and big sand blown by wind. Annual precipitation is 130 ~ 250 mm, annual evaporation capacity 1,100 ~ 2,400 mm. Its main crops are wheat, rice, cotton, etc.

Ningmeng irrigation area has convenient irrigating condition with long agricultural history. It is the important grain, oil and sugar producion base in two municipalities and also in china. The total output of industry, agriculture, average financial income, average farmer family's net income and life consumed payout in Ningmeng irrigation area are higher than other irrigation area and the average level of two municipalities.

2 Water resources use status and existent problem

2.1 Water resources use status

The Yellow River is the main river in Ningmeng irrigation area, hasing abundant water source and good water quality. It is the main irrigated using water. In Ningxia Province the mean annual discharge is 1,030 m^3/s, water quantity of flow is 32.50 billion m^3. The mean annual entered water amount of Inner Mongolia (1956 ~ 2000 year's series) is 28.70 billion m^3, the output amount is 22.91 billion m^3. According to the Yellow River available water supply distribution project approved by state council in 1987, the allowable consumption use of the Yellow River in Ningxia Province is 4.00 billion m^3, 5.86 billion m^3 in Inner Mongolia before south – north water transfer project.

The direct runoff rate of Ningmeng irrigation area is very small, and of strong seasonality. It is hard to make use of. The replenishment of underground water in the irrigation area are rainfall infiltration, mountain side refill and surface water infiltration. There is a little available usage of underground water.

According to statistics in 2000 ~ 2002, the average quantity of diverting water from the Yellow River was 14.828 billion m^3, used underground water 1.964 billion m^3, thereinto irrigated water 15.982 billion m^3, that in industry and life 1.499 billion m^3. The consumption use of the Yellow River was 8.355 billion m^3, underground water 1.268 billion m^3, thereinto the consumption use of agriculture was 8.995 billion m^3, other 0.677 billion m^3.

2.2 Main problems

2.2.1 Scarce water resources and serious water waste

Ningmeng irrigation area is the best economic developed region in the two provinces, the quantity of water diversion in it has exceeded the distributed guideline. Along with increase of urbanization rate, change of industrial and agricultural structures, strongly increased water use in life and industry in the Yellow River basin, and the same in environment construction and wet land protection and other water using department. Because of climate change and human being action, in the last 20 years, average precipitation of the Yellow River basin decreased 5% ~ 10%, riverway's inflow lessened, ground evaporation rate heightened, water resources quantity reduced. The status will prick up hereafter.

Because of historic reason, many canal and farm structures and their auxiliary projects were aging badly. Through many years' operation, many of them exceeded design life and operated in bad condition. Irrigated use efficiency is low, over a half irrigated water waste in canal water transfer and farm infiltration, water is wasteed badly.

2.2.2 Unreasonable water use structure

There are three aspects: firstly, unreasonable industrial water use structure. The proportion of agricultural water use is big, and small in industry. According to the two provinces' water use structure, the proportion of agricultural water use are 93.3%, 90.6% respectively; and 5.5%, 4.6% in industry. Secondly, unreasonable resources use structure. The Yellow River is the main irrigated water source, the proportion in total using water is over 90%. Thirdly, there is unreasonable agricultural water use structure. Crop structure adapt to the status of short age of water; the crop that needs plenty of water occupied big area, the opposite crop is little.

2.2.3 Deteriorated water environment

There are four facets: firstly, salting of soil. The irrigation area was always free flooding and bad drainage, causing salting of plantation. Second, deteriorated water environment in some places. Along with rapid develepment of industry and city, and lack of environment fathering, adding to bad environment protection consciousness, water source of underground and surface was polluted badly, water environment was deteriorated. Third, the groundwater of important city in irrigation area was overdrafted. The factories in Yingchuan and Shizuishan City are very centralized. They overdraft the groundwater, so the water table descended and formed underground depression.

2.2.4 The irrigation area water price system doesn't adapt to market economy

Because the unreasonable water price system and present water price is only 30% ~ 40% of cost, the income is not enough to support operation and service in irrigation area. This water price system minified people's water saving consciousness, pushed lagging irrigated manner, blocked the popularize of new water saving technique, therefore, the status of contrived water waste is very serious.

3 Basic condition of water right transfer in Ningmeng irrigation area

As the experimental unit of water transfer, the work in Ningmeng irrigation area started in 4th, 2003 in the Yellow River Basin. There are 5 items approved at present, thereinto, 2 items in Inner Mongolia, 3 items in Ningxia. The total quantity of water saving of experimental project is 98.33 million m^3, thereinto, 44.48 million m^3 in Inner Mongolia, 53.85 million m^3 in Ningxia. Quantity of the water collected from the Yellow River for transfer in items is 83.83 million m^3, thereinto, 39.23 million m^3 in Inner Mongolia, 44.60 million m^3 in Ningxia. The total investment is about 0.327 billion yuan, thereinto, 0.175 billion yuan in Inner Mongolia, 0.152 billion yuan in Ningxia. The average investment for one cubic meter water is 3.32 yuan, 3.93 yuan, 2.82 yuan in Inner Mongolia and Ningxia respectively. The average water price for transfer is 0.13 yuan/m^3, 0.157 yuan/m^3, 0.113 yuan/m^3 in Inner Mongolia and Ningxia respectively. Except above 5 experimental items approved, 9 items have been checked up and approved by YRCC in Inner Mongolia. Thereinto, there are 5 thermal power projects, installed capacity 4,800 MW, 2 coal power projects, installed capacity 3,600 MW, 1 sodiumhydroxide, PVC project, installed capacity 1,200 MW, 1 carbinol, dimethyl enther project. Quantity of the water collected from the Yellow River for transfer in the 9 items is 66.438 million m^3; corresponding gross water saving quantity is 71.765 million m^3; total investment is 0.347 billion yuan. The irrigation area that participates in water right transfer contains southern bank area of yellow river, Chengkou irrigation area and Luanjingtan irrigation area in Inner Mongolia. Thereinto, there are 6 southern bank irrigation area, water saving quantity 56.175 million m^3, 2 Chengkou irrigation area, water saving quantity 12.40 million m^3, 1 Luanjingtan irrigation area, water saving quantity 3.19 million m^3.

4 Effect of water right transfer

4.1 Adding investment in channel of irrigation area, boosting water use efficiency

Because of historic reasons, many hydraulic projects are aging badly. Many of them overrun design life and operate in bad condition. Because of lack of ban is kroll, it is hard to carry out water saving alteration in the irrigation area. So water resources waste heavily and water use efficiency is low. Through water right transfer, alienee whom someone transfer water to invest in water saving alteration in irrigation area of assigning party who transfer water to alienee, then assigning party give the quits water that is the saving water to alienee. From the 14 approved items on water right transfer, we know, the water that alienee obtained from assigning party is the saving water that is from water saving alteration. Water collected from the Yellow River for transfer is 0.150 billion m^3 between Ning and Meng, that need 0.347 billion yuan investment in canal lining, then saving water 0.170 billion m^3. This mean, after accomplishment of the 14 transferred items, the irrigation area that carrys out water right transfer will decrease 0.170 billion m^3 irrigation engineering conveyance loss. At the same time, canal water used efficiency become very high; velocity of flow become fast; irrigation interval becomes short. It boosts irrigated degree and irrigated dependability of crop, irrigation water use efficiency and a cubic meter yield factor is enhanced consequently. According to correlative study, after accomplishment of the 8 water right transfer items of southern bank irrigation area in Inner Mongolia, canal water used efficiency will reach 0.72, irrigated water used efficiency will be from 0.32 to 0.65.

4.2 Altering water use structure of irrigation area, heightening water resources use efficiency

At the present time, agricultural water use benift is low, the opposition is in industry in Ningmeng Irrigation Area. According to analysis, one cubic meter benefit is 0.97 of agricultural, 57.9 for industry in Ningxia. The present water use structure, one side, it hindered the industrial development that have high water use benift because it blocks the industry obtaining needed water quantity; on the other hand, it makes agriculture have abundant water, it causes a mass of wasting water. because of lagging water work and control level in agriculture, Through water right transfer, some water used by agriculture is transferred to industry, it heightens industrial water used dependability, boosts industrial development, enhances water use benifit and makes the water use structure become reasonable in Ningmeng irrigation Area. Depending on present water right transfer, if we accomplish water trade on plan, there will be total 0.150 billion m^3 water transferred from agriculture to industry, thereinto, 0.045 billion m^3 in Ningxia, 0.105 billion m^3 in Inner Mongolia. Regardless of other changed condition, proportion of water used by agriculture is from former 92.9% and 92.0% to present 91.7% and 90.6% respectively in Ning and Meng; that of industry is from former 5.5% and 4.6% to present 6.6% and 5.9% respectively.

4.3 Effect of water right transfer on environment

Groundwater resources of Ningmeng irrigation area is abundant, shallow ground water and confined water mainly. Buried depth of shallow ground water is connective to terrain and irrigation closely. Low hypsography area has low buried depth, lofty hypsography area has deep buried depth, irrigation area has low buried depth, unirrigated area has deep buried depth. Water right transfer of irrigation area is that industry invest in water saving alteration, then gain the water that is saved through canal lining and so on. Because of water saving alteration, seepage loss of transfer, distribution and field irrigation is decreased and it save vast water, but it reduce replenishment of groundwater, the water table descend. For Ningmeng irrigation area, because of strong evaporation and low water table, evaporation of shallow ground water is decreased, then salting of soil is mitigated; on the other hand, because of little precipitation, growth of natural vegetation rely on groundwater mainly in irrigation area. There are lake and swamp in Ningmeng irrigation area. Decline of water table cannot but change survival conditions of marsh and natural vegetation, then affecting ecosystem of irrigation area accordingly.

4.4 Effect of water right transfer on runoff of yellow River

There are two aspects, one is on quantity of runoff; another is on water quality of riverway. Through water right transfer, Investment in channel is added, enhancing water use efficiency of irrigation area, altering water use structure of irrigation area, boosting water resources use very efficiently. While water right is transferred, on account of different water collecting course between industry and agriculture, water collecting course of irrigation area will change, then it affect cisborder runoff process of Yellow River, especially in dry season. In addition, water used for transfer is part of water loss that is saved by water saving alteration, that isn't useless in irrigation area, much of them replenish groundwater in regression, then flow into riverway as the form of runoff. If that water is transferred to industry, much of them will be consumed. Thus it can be seen, water right transfer adds local water consumption of the Yellow River actually, it will decrease the recession of irrigation area.

5 Conclusions

From the above analysis, we can see, by means of water right transfer, some water used by agriculture is transferred to industry. That heighten industrial water used dependability, boosting industrial develepment, enhancing water use efficiency and make the water use structure become reasonable in Ningmeng Irrigation Area. Through water right transfer, salting of soil is mitigated; local environment is improved. But carrying out water saving alteration will change replenishment of groundwater, it affects local and circumjacent underground aquatic environment consequentially. In addition, agricultural using water is transferred to industry, that would affect runoff of Yellow River. Therefore, when we carry out water right transfer, we should know this:

(1) Estimating water quantity for water right transfer accurately. Owing to close connection between groundwater and runoff of the Yellow River in Ningmeng Irrigation Area, the amount of saving water is unequal to decreased water collected from canal head, the saving water should be equal to former water collected from canal head minus present water collected from canal head minus reductive groundwater replenishment. So the gaining water coming from water right transfer cannot be regarded it is equal to decreased water collected from canal head.

(2) Feasible scale of water right transfer. Ningmeng Irrigation Area is in northwest of china that is dry and rainless. It's environment is very flimsy; growth of natural vegetation and marsh depend on groundwater in irrigation area. In order to maintain the environment, the buried depth of groundwater must be appropriate. Because of water right transfer, water table would descend consequentially, different scale for different water table. Therefore, when we carry out water right transfer, we ought to ascertain reasonable scale of water right transfer considering the proper water table that is required by environment.

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A Shallow Discussion of the Property Ownership of the Water Right

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Abstract: With the fast evolution and the all – direction promotion of the society, along with the gradual increasing of the population, water shortage has become the bottleneck for the sustainable development of the economic society of our country. Besides, the imperfect existing water right system also lead to the lacking of the laws for the water right, which results in the inconvenience of transferring the water right and a lot of disadvantages on the protection and utilization of the water resource and the intensifying of the conflicts between the supplying and demanding of the water resource. On viewing this, the authors will take about the existing water right system in our country and the transferring of the water right.

Key words: water right, ownership property, beneficial ownership property, the right of owning and utilizing the water resource

Water is the essential basis of the living creature and the development of the society, but with the development of the industrial cities, conflict between water supply and demand becomes a world wide issue. Our country is among one of the 13 countries which are short of water. At present, the average quantity of resource is 1/4 of that of the world, and the distribution is not balanced. Under the moving of the high – speed development of the society and the all – around promotion, the demanding of people to the water increased day by day, while the water is severely polluted and the efficiency of water utilization is low, the conflict between the supplying and demanding intensified and the water resource will limit the sustainable development of the economic society of our country. Therefore, it is of great urgency for our country to reform and improve the existing water ownership system and build the highly efficient relevant management system which adapts to the market economy system of socialism.

1 The water resource ownership system in our country

The 9 th item of the Constitutional Law formulated clearly that the water resource belong to the country, the 3 rd newly revised Water Law also clearly provides that the water resource belongs to the country, the ownership of the water resource is exerted by the State Council to represent the country. The pools of the collective economic organizations and the water in the reservoirs built by the collective economic organizations in the countryside should be controlled by the collective economic organizations in the countryside for use. That means that the country id the only main body of the ownership of the water resource, which has the right to own, use and receive the benefits from the water resource. Meanwhile, it also implies that the ownership of the water resource can't be transferred.

According to our country, the country's ownership of the water resource is inevitable.

(1) From the characteristics of the water resource itself, the water is the essential and couldn't be replaced, and it is the critical strategic resource for people's basic survival and the economic development.

(2) The water resource is rare and finite, which determined that the water resource should be the collective property of all the people rather than the personal property of an individual. It stands for the public interest of the society, so its ownership and management rights should be carried out

by the civil subject which stands for the public interest. Since the country is the only representative of the public interest, when the individuals' interest conflicts with the social interests, the immediate interest and the long – term interest, the country should regulate the behaviors based on the overall interests and take measures to carry out the united management and control of the water resource. For example, after the united dispatching and control for the Yellow River, the frequent breaking condition has been changed and a certain amount of water is maintained, which shows that the maintenance of the Yellow River and the utilization of it is very effective.

(3) The country's ownership of the water resource could be authorized to the society by the system, the macroscopic control and supervision could be maintained to lay a legal foundation for the exploration and the overall management of the water resource by our country.

2 The water ownership system in our country

The water ownership is the name of a series of the utilization of the water resource, that is, the obligees owns the rights of utilizing and benefiting of the surface water and the underground water to a certain extent by law. During the process of carrying out the state ownership, the ownership system is decisive to the exploration and utilization of the water resource. Therefore, as the political subject, the country can't directly occupy, utilize and benefit from the water resource, the main way is to admit the specific subject to use the water resource and charge the users to realize the ownership.

The 6 th and 7 th items of the newly revised Water Law provide respectively that the country encourage the units and individuals to explore and utilize the water resource by law and guarantee the legal water taking admission system and compensated usage system, but the water in the pools of the collective economic organizations and the water in the reservoirs built by the collective economic organizations in the countryside are exceptions. That is, anyone or any units who takes and uses the surface water and the underground water should apply to the executive departments legally, except for those who are not required to apply for the usage by law. In addition, the State Council issued Water Taking Permission measurements and each province and city as well as the valley organizations issued some concerning laws such as the Detailed Regulations for Water Taking Permission measurements, which ensure that the water executive departments are entitled to the application and the water taking certificate, and collecting the water fees, etc. While the users are entitled to using the water resource and benefiting from it.

At present, for the subject of the ownership of the water, it could be the specific units or individuals, and the object of the ownership; it includes all the water resources within the country, such as the rivers, lakes and the underground water. The rights include water taking right, water storing right, letting out right, water transporting right, electrical right, and the tourist right, etc. Besides, the water ownership should be an open right and enrich its contents with the development of the society.

3 The existing problems for the present ownership system

At present, there are concerning laws designed for the regulations of the water ownership in our country, for example, some systems to protect the units' and the individuals' legal right of using and the exploring of the water resource, the water taking permission system and compensation usage system. But in general, the laws in this field are still not perfect and limitations still exist.

The subject and the detailed regulations for the water ownership are not clear. The regulations for the usage of the water resource are not so clear, which caused the misuse, waste and pollution of the water resource. As a result, the water resource is lacking and influences the social stability and the economic development.

The utilization of the water resource in our country hasn't achieved the most optimum distribution system, and enormous ineffectiveness and waste still exist. Therefore, the water ownership system should be improved by enforcing the law and united plans and enlarge the running of the water ownership.

The existing laws don't have strong regulations for the utilization and the management of the water resource, the hard items are not adequate and the enforcement power granted to the executive department few, and the punishment for the destroyers and the wasters of the water resource is light. At the same time, the measures for the scientific water taking and the policies such as the low water price have caused a lot of problems.

4 The concept of the water right ownership

In order for the further protection and utilization of the water resource in our country, the deceleration of the conflicts between the supplying and demanding, the exaltation of the utilization as well as the giving full play to the market mechanism, it is of great necessity to locate the water right system to the category of the ownership of property, and grant a certain power to it.

4.1 The ownership of property system in the civil law

The ownership property in the civil law refers to that the obligee exercises the direct mastery to the specific objects, and excludes the other people's interference in it. It mainly includes: the mastery to the specific object itself, that is, exercises the right to its property and excludes the other people's interference in it. These two rights are closely related to each other, the latter one supplies the guarantee for the former one. The ownership property consists of self ownership and other ownership. The self ownership is also called ownership, which refers to the exclusion of other people's interference in mastering the object. The ownership refers to the rights of occupying, utilizing and the benefiting as well as punishing. The other ownership refers to owners could enjoy the direct mastery of the objects to a certain extent. The other ownership includes beneficial real right and the guarantee right, while the beneficial right is critical.

4.2 The water right is a kind of beneficial ownership right

(1) The so called property ownership of the water right refers to the location of the water right system within the category of the civil law, giving protection to the water real right and making the real utilization right of water becomes a kind of beneficial ownership right, and possessing the common properties of the beneficial ownership property.

(2) From the strategic prospective, the water resource becomes more and more rare, and its value becomes prominent. Therefore, water gradually belongs to the category of the object in the civil law, and the water right belongs to the ownership property, people use this kind of ownership property to satisfy the needs of life. According to the new tendency that the modern ownership property develops to the natural resource ownership, the content of the water right gradually becomes first and has become the most important ownership of property in the modern society objectively.

(3) The water right, as a kind of beneficial right, not only grants the investor of the water the utilization and benefiting right to the water resource, but also excludes any illegal interference and prevention. This is because that the water right has the property attribute by the civil law, and makes the optimizing of the allocation of water resources possible. Of course, the utilization of the water resource is finite, it could be the owners' duties to the country and society; it could also be rational and undertaken by the clients.

4.3 The meaning and the function of the water right

(1) The real right property of the water right should be made clear to further the strengthening of the protection to the owners of the water fight and promote the healthy development of the hydraulic career. That is because the water right possess the essence of the attribute of the ownership property, which means that under the permission of the obligee, he could has the

exclusive benefiting right for a certain amount of water in specific districts in some degree. Thus the obligee could benefit from exercising his power for a certain amount of water in specific districts. In addition, when the obliges are interfered in the process of realizing his interests, he could ask for instructions to get rid of the interference. When the production is damaged, he could apply for the compensation. The privilege of the ownership of property could ensure and protect the legal interest of the obliges and effectively prevent the third – part interference. Besides, it could also promote the transforming of the government' s functions and improve the measures to raise the efficiency of the executive administration.

(2) Defining the attribute of the ownership property of the water right could make the adequate utilization of the water resource reasonable. The country should make some concerning laws and realize them through the characteristics and the effects of the ownership of property. Therefore, as a real right established by the law, under the support of the law, it will realize its value through the market control. When the water right goes into the market, the owners will enlarge the water source and open the source and the streams to explore new ways to make the hydraulic investment plural and protect and improve the quality of the water. In this way, the finite water resource could not only be utilized sufficiently and effectively, bout also helps to improve the quality of the water and improve the hydraulic facilities and service so as to raise the unitization rate.

4.4 The limitation of the real right of the water right

The real right is a private right, so the including of the water right into the real right is also a private right. But because our country carries out the state ownership of the water resource, the water right is a beneficial right and derivative. Therefore, the water right possesses the characteristics which are different from the common real right. It is a private right granted by the public right. Because of this reason, the water right is called to be the permission ownership right.

(1) Because the objective water resource of the water right is rare and owns the functions of ecological environment and the public interest, it becomes a public object, which requires the government to supply and protect it by the market tool. So the water right should be limited by the public interest.

(2) Thought the water right system emerges from the needs of protecting the water right owners and the optimizing the allocation of resources, as the owner and the macroscopical control of the economy, the government has the right of the microscopic administration of the water resource. The water right system, as an allocation tool of the water resource, is one of the essential components of the water allocation system, and should be subjected to the water executive organization' s programming, the total amount control, the water supplying allotment, the check and supervision, etc. Then the sustainable protection and development of the water resource will be in harmony, the two resource allocating principles—fairness and efficiency could be satisfied.

(3) Since the water right derived from the water resource ownership, the regulating, changing and ending should be interfered by the government in a certain degree and limited by the law. During the utilization of the water resource, we should also pay great attention to the prevention of the pollution, water saving, water and soil reservation as well as the environment protection. The public function of the water resource should also be taken into consideration, such as the prevention of fire, provide relief to the disaster, national defense and the development of the science and technology.

5 Conclusions

As is mentioned above, the existing water right system lies in the subject of the water right and the disadvantages also exist, such as the unclearness of the content and the lacking of the legal enforcement. In light of the ownership of property to locate the water right system in the civil law, the positive role of the market economy could be displayed and the efficiency of water use could be promoted to relieve the intensifying of the conflicts between the supplying and demanding of the water resource.

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