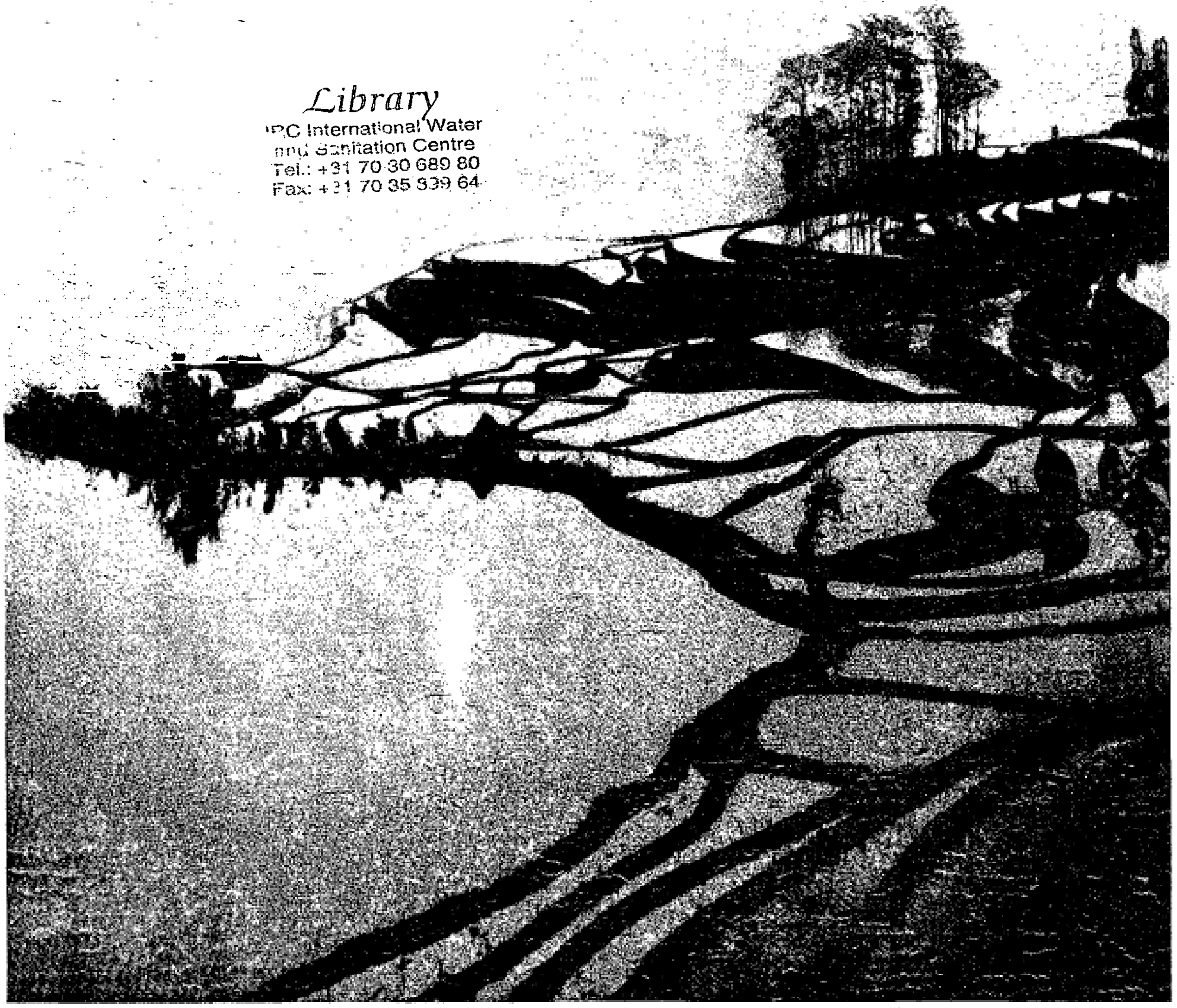
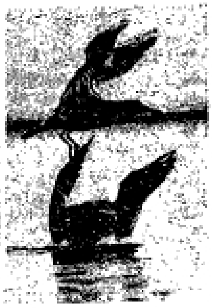
Second World Water Forum

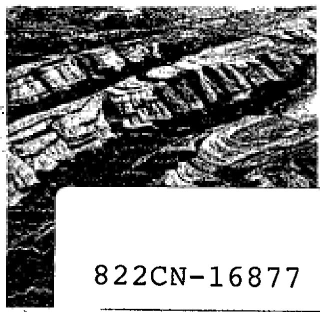
China Water Vision

Meeting the Water Challenge in Rapid Transition

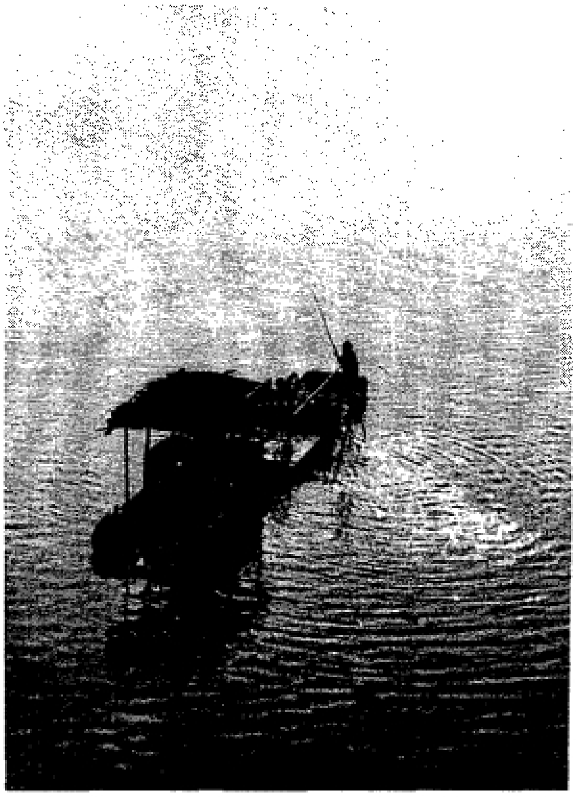
March 20, 2000



The Hague, the Netherlands, March 17—22, 2000



Water ecology is dealing with the relationship between water, man and nature. According to Lao Dan, a famous ancient Chinese philosopher, it is "such a thing which seems to forth from nowhere, and yet it penetrates everywhere". "It is formless, shapeless, vague, indefinite, imperceptible and indescribable, always changing, and reverting to the state of nothingness".

Contents

The 2nd World Water Forum

Regional Session

China Water Vision:

Meeting the water challenge of in rapid transition

(9:00 am – 17:30 pm, March 20, 2000)

Coordinators: Rusong Wang

1. Introduction

China is one of the most populous countries with its per capita water resource less than 35% of the world's average. The uneven water distribution in time and space has made the available water resource much less than the statistics. The rapid rural industrialization and regional urbanization in recent decades, while bringing prosperity to people, have exerted severe ecological stresses on water system. The crucial water shortage in industry, agriculture and domesticity, the widespread water pollution from cities and agriculture, the increasing ecosystem deterioration caused by inappropriate water exploitation, and the increasing frequency of flooding and drought, have been threatening its social and economic development and people's health. Creating and sustaining healthy living conditions for 1.2 billion Chinese, one fifth of the world population, is therefor a growing concern and big challenge for China's sustainable development. Awakening from the Yangtze Basin flooding, Yellow River drying, and heavy pollution of some watersheds in recent years, people are more and more concerned with the water issue in China. The session will focus on current and future water issues in China, such as water states, water stresses, water security, water systems, and water strategies for making trade off between risk (wei) and opportunity (Ji), of which consists the Chinese word "crisis (wei Ji)".

2. Program

Session I: 9:00 – 10:30, **Chairperson:** Rusong WANG

9:00 – 9:30

Changming Liu, Professor, Academician, Chinese Academy of Sciences: **China's regional water issue and its strategies in 21 century**

9:30 –10:00

Gerhard K. Heilig, International Institute for Applies Systems Analyses (IIASA), Laxenburg, Austria: **Can China feed itself?** (to be confirmed)

10:00 –10:30

Rusong Wang, Professor, Chinese Academy of Sciences: **Water-Man Eco-Complex and Its Security Scenario in China**

10:30 –11:00: ***Cofee brteak***

Session II: 11:00 – 12:30, **Chairperson:** Changming Liu

11:00 –11:30

Wenhua Li, Professor, Academician, Chinese Academy of Engineering Sciences: **The ecological concerns of water related disaster in China**

11:30 –12:00

Richard Reidinger, Principal Agricultural Economist, Beijing Office of World Bank, **Irrigation in China's agriculture -- risks and chances**

12:00—12:30

Zhiyun Ouyang, Professor, Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences: **China's water environment and the future ecological options**

12:30 –14:00 Lunch

Session III: 14:00 – 16:00, **Chairperson:** Wenhua Li

14:00 –14:30

Xiaoliu YANG, Professor, Director, Department of Water Resources, China Institute of Water Resources and Hydropower Research: **Strategic options for China's Water Sector**

14:30 –15:00

Kenneth Strzepek, Professor, Stockholm Environment Institute: **Local implementation of the World Water Scenarios: A Case Study of Water Management in the Yellow River Basin in China.**

15:00 –15:30

Lida Weng, The Yangtze Valley Water Resource Bureau: **China's water issue in main watersheds and its strategies**

15:30 –16:00

Zhang Jingsheng, China Tangtze Three Gorges Development Corporation, **A Brief Introduction to Environmental Impacts Statement for the Yangtze Three Gorges Project**

16:00 – 16:30 Cofee break

16:30 – 17:30

Session IV: (Panel Discussion) Meeting the Challenge of Rapid economic and social transition in China

Chairperson: Richard Reidinger

Panelists: Changming Liu, Lester R. Brown, Wenhua Li, Gerhard K. Heilig, Rusong Wang, and Xiaoliu Yang

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Water Resources Development in the First Half of 21st Century in China

Changming Liu

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Abstract: This paper mainly deals with problems of water resources in China. Based on the projection of the gross national economy and social development in the first half of the 21st century, the author indicated that the gross demand for water resources would be continuously increasing. Both industrial and domestic water requirements would have a higher increasing ratio in comparison with water consumption of agricultural sector. It is estimated that the growth of water demand in China would be stable in terms of zero growth after year 2050. The author, finally, discussed the countermeasures to the problems in nation's water resources as well.

1. An estimation of China's economy and social development

(1) Population increase. By the end of 1990, the population of China was 1.143 billion. Under the condition of strictly implementing the One Child Policy for controlling population increase, the estimated average ratio of population growth during 1990-2000 is about 1.292%(gross birth rate is about 0.22%), and the population of China would be 1.3 billion by the year 2000; the estimated average ratio of population growth during 2000-2020 would be about 0.721%, and the population of China would be 1.5 billion; the estimated average ratio of population growth during 2000-2050 is about 0.22%(we are striving for reach zero growth by 2050), and the population of China would be 1.6 billion.

(2) Industrial production growth. One major way to increase national income is to increase industrial output value. In the reports of the Eighth Five-Year Planning approved by the 8th National People's Congress, the planned rate of GDP growth was modified. The rate was turned up for 6 % to 8%-9%(take 8.5% when calculating), the GDP in both agriculture and industry sectors would be increasing by this rate approximately. The average annual growth ratio of GDP in agriculture sector was 3.5%. At the same time, according to a report from the Study Group on National Condition Analysis, Chinese Academy of Sciences, the average annual growth rate of China's GDP will be 6-7% (take 6% when calculating). Besides, in order to make China become a median level developed country, the growth rate should be kept at about the level of 5% (table 1). Accompanying the economic development, the structure of national economy will also change step by step. The first and second industry will weigh less, and the third industry will weigh more.

(3) Growth in food demand and its requirement for the area of developing farmland irrigation. In 1990 the gross food output was 435 billion kg, per capita amount of grain was 384 kg. According to the nation's planning, the gross food demand should reach 520 billion kg in the year 2000 and per capita amount of grain should reach 400 kg. Concerning a limitation in both cultivated land area and cultivable land in the country, the food production will be very tough. Efficient ways to increase the cereal production are to increase the unit production and increase arable land with reclaiming wastelands to compensate cultivated land losses caused by urbanization and the construction of mine industry and other industries. The method to increase the unit production is, besides the agricultural technique popularization and crop breed improvement, to enlarge the valid irrigation area in water conservancy, improve productivity of the middle and low yield farmland, further mitigate losses resulting from flood and drought disasters.

The total irrigated land is about 48.67 million ha, which accounts for less than 50% of the total cultivated lands in China. According to "China Water Resources Utilization", the valid irrigated land would reach 54-35 million ha (table 2). It is necessary to enlarge irrigation area in order to increase food self supply rate in the 21st century. By year 2050, irrigation land is targeted to reach 60-65 million ha, including wasteland reclamation of 10 million ha. The unit cereal production would reach 15000kg/ha under the condition of all the measures working well. To reach this goal, 2 million ha irrigation land should be increased per a decade during 2000 to 2050.

Table 1. Estimation of China's Economy Development in 21st Century

year	GDP (billion Yuan)	increment rate (%)	structural ratio of different industries in %		
			1st industry	2nd industry	3rd industry
1990	1740	8.5	27.50	45.33	27.20
1992	2400	8.5			
2000	3734.1	8.0	20.64	48.80	30.56
2010	7045.4	6.0	16.00	48.00	36.00
2020	12617.2	5.0	12.78	47.22	40.00
2030	20552.1	5.0	11.00	45.00	44.00
2050	54530.9		10.00	40.00	50.00

Table 2. Irrigation land and irrigation quota in 2000

Region	Arable land (10^4 ha)	Irrigation land (10^4 ha)	Gross irrigation duty (m^3/ha)
Northeast Rivers	2018	448	8400
Haihe and Luanhe Basin	1118	675	5250
Huaihe & Shangdong peninsula	1522	887	7050
Yellow river Basin	1298	433	7200
Yangtze River Basin	2449	1718	9825
South China Rivers	693	521	14400
Southeast Rivers	261	220	10125
Southwest Rivers	179	73	8025
Inland Rivers	593	220	9975
China	10131*	5435	8925

* A new figure is 13000 (10^4 ha)

2. Water Demand Estimation in the first Half of 21st century

Water Utilization Estimation for Industry. Water utilization for industry was 50 billion m^3 in 1990, with 396 m^3 per 10 thousand Yuan output value. Along with popularization of water-saving techniques and measures in industry and widely water saving administration enhancement, water price and water recycling rate increment (the water recycling rate will rate 85% in year 2050), according to water saving status in North China, water utilization amount per 10 thousand Yuan industrial output value reduced 6% yearly during 1990-2000, and further 4% reduction for 2000-2010, 3% for 2010-2030, 2% for 2030-2050. Upon this calculation, water utilization amount pre

10 thousand Yuan output value would much reduce by 2000. Water utilization amount of industry in the first of 21st century is listed in table 3.

Table 3. Estimation of Industry water use in the first half of 21st century

Year	Industry production value (billion Yuan)	water withdrawal (10^8 m^3)	water use reduction rate per unit industrial product (%)	quota ($m^3/10^4$ Yuan)
1990	1262	500	6.0	396
2000	3122.1	665	4.0	213
2010	5918.1	929	3.0	157
2030	18085.1	1899	2.0	105
2050	49077.8	3436		70

Estimation of water consumption for urban life. The water supply for urban population was 180 million in 1992 in China. Along with speeding up of the urbanization, the urban population will increase rapidly, especially in the southeast coast regions and Zhujiang delta. Meanwhile the standard of water utilization for urban residents is increasing gradually. It is estimated that China's urban population for water supply will amount to 280 million, its water consumption will be 185 liter per day per capita in 2000; by year 2010, urban population will be 350 million and water quota will be 210 liter per capita per day; by year 2030, urban population will be 500 million and water quota be 250 liter per capita per day; by year 2050, urban population 800 million and water quota 250 liter per capita per day. The Water utilization amount for urban life is listed in table 4.

Table 4. Estimation of urban life water use in the first half of 21st century

year	population for water use (10^8)	Water use indicator (L/day per person)	water use amount (10^8 m^3)
2000	2.8	185	189
2010	3.5	210	268
2030	5.0	250	456
2050	8.0	250	730

water use for agriculture. Based on social and economic development estimation in 2000-2050, considering nature condition, China's irrigation land will increase from 54.35 to 60-65 million ha, water use in agriculture will increase accordingly. In same time, China's gross irrigation duty will decrease heavily along with social progress, science and technology development, irrigation and water saving technique improvement especially water saving irrigation technique popularization and application. The gross irrigation duty was 9600 m^3 per ha in 1980, it is estimated that this will be reduced to 8925 m^3 by 2000 and 7500 m^3 in 2030. It will bottom to the limitation in 2050(see table 5).

China's irrigation water amount sees table 6.

Estimation of water demand in the first half of 21st century in China. The above research results out the total water demand for agriculture, industry development and people life in the first half of 21st century (table 7).

The table 7 indicates that agriculture water use is still accounts for major water use ratio, its ratio is decreasing from 85% in 2000 to 49.9% in 2050, the total water demand for agriculture is also decreased from 484.8 billion m^3 t~ 415.7 billion m^3. The reduction is 69.1 billion m^3, and this will be very useful for China's water conflicts between water demand and water supply.

Table 5. Estimation of Irrigation Area Distribution and gross quota in 2050

Region	irrigation area (10^4ha)	gross duty (m^3/ha)	Water taking (10^8 m^3)
Northeast Rivers	600	4500	270
Haihe and Luanhe Basin	900	3750	338
Huaihe & Shangdong peninsula	1150	5250	604
Yellow river Basin	700	5250	368
Yangtze River Basin	1850	7500	1388
South China Rivers	550	12000	660
Southeast Rivers	250	9000	225
Southwest Rivers	100	6750	68
Inland Rivers	350	6750	236
China	6450	6445	4157

Table 6. Estimation of Agriculture irrigation water use in the first half of 21st century

Year	irrigation area (10^4 ha)	gross irrigation duty (m^3/ha)	water withdrawal (10^8 m^3)
2000	5435	8925	4848
2010	5640	8250	4653
2030	6040	7500	4530
2050	6450	6445	4157

Table 7. Total Water use in the first half of 21st century

Year	Agriculture water use			Industry water use			Urban life water use			Total (10^8 m^3)	Total (10^8 m^3)*
	Water amount (10^8 m^3)	Incre-ment rate (%)	ratio (%)	water amo-unt (10^8m^3)	Increment rate (%)	ratio (%)	water amo-unt (10^8 ^{3})	increment rate (%)	ratio (%)		
2000	4848	-0.41	85.0	665	3.34	11.7	189	3.56	3.3	5702	
2010	4653	-0.13	79.5	929	3.64	15.9	268	2.69	4.6	5850	6748
2030	4530	-0.43	65.8	1899	3.00	27.6	456	2.38	6.6	6885	7350
2050	4157		49.9	3436		41.3	730		8.8	8323	7590

* Updated figure

Since industry production value increase rapidly, water demand will increase continuously in spite of industry water use quota reduction. Industry water use will increase from 66.5 billion m^3 in 2000 to 300 billion m^3 in 2050, with annual increment of 3.34%, among which the increment rate is 3.34% in 2000-2010, 3.64% in 2010-2030, and 3% in 2030-2050 respectively. Industry water use will increase from 11.7% in 2000 to 41.3 in 2050. Urban life water use amount will increase rapidly but with a relative moderate ratio and absolute figure comparing to agriculture and industry. The ratio will be 8.8% of the total water use in 2050. The total water resources demand will increase from 570.2 billion m^3 in 2000 to 832.3 billion m^3 in 2050 with increment of 46%. Among which 0.26% increment annually in 2000 to 2010, 0.82% increment in 2010 to 2030, 0.95% increment annually for 2030 to 2050. It is estimated that the water demand will reach a stable status by 2050.

3. Discussion on Major Strategic Aspects

(1) Interacted water problems and harmonious development

There are many water related problems in China. Generally, they can be summarized into three groups: Firstly, the severe contradiction between water supply and water demand in cities and rural areas. There are more than 300 cities in China suffering from water shortage, and the actual irrigated area accounts for only 40% of the total arable land. The second group belongs to the frequent occurrence of floods, water-logging and drought. The annual loss caused by floods and drought makes up 60-70% of the total loss caused by various natural disasters. Thirdly, it is the serious water pollution. Especially south China, where water is abundant, is subject to water shortage due to water pollution. The three groups of water related problems mentioned above all have close relations with humans, water and the environment. Therefore, the harmonious development of human, water resources and the environment is the most important solution for the sustainable development and rational utilization of water resources in China. In a word, the development and utilization of water resources must be continuous and sustainable.

(2) Demand Management Concerning Zero Growth

Both creating new sources and the conserving water resources are two of the most important approaches for water supply. However, the management of water resources remains as important as ever. It is a pressing need to get rid of the habit of paying more attention to construction a new water project than its sound management. Water management involves many issues, such as policy, legislation (law and regulations) institution, organization, personnel, finance and operation. Water management work on water resources must focus on their rational use. Obviously, the core of the rational use id water saving. So, water saving is the main task for water resources management. The ultimate target is to realize the zero growth in water withdrawal.

(3) Equal development in Nation's Territory Management

In view of distribution, water resources can be divided into two types: one is the concentrated water resources with the feature of high intensity of water flow rate in a short recovery period for replenishment, such as river water and easily recharged shallow groundwater. the other is the discrete water resources with the feature of low intensity of water flow rate covering a large area. If the water flow rate of concentrated water resources is measured by unit of m/s, while mm/m is used for the discrete rainwater, clearly there is a difference of 10^5 in value. So, we call the former "strong" water and the latter "weak" water. Although the intensity of "weak" water is very low, it can be intensified by artificial concentration measures to do water harvesting. Now rainwater utilization is the main trend for water resources development in the world. It is necessary for China to carry out an equal development of "strong" and "weak" water in its vast continental territory and more than 3.5 million km^2 of territorial seas so as to realize the rational allocation and regulation of its water resources to meet the requirements for the development of economy.

(4) Rational Utilization of Sea Water And Brackish Water

Since the reform and opening policy began in the early 1980s, China has increasingly faced a serious contradiction between supply and demand in water resources, especially, in its coastal economic zones. As for the amount of water deficit, the place where the problem is most serious is not in the arid northwest, north and northeast (so called three "N" areas), but the southeastern coastal cities and urbanized areas, which are under humid and rainy conditions. The water deficit in these areas accounts for almost half of the total water deficit of 114 cities suffering from severe water shortage in the country. Therefore, developing seawater utilization is of great significance in all coastal industrialized areas, particularly in meeting the high consumption of cooling water. Now, some techniques have been relatively successful in solving the corrosive problems in the use of seawater. The cost of sea water used for cooling processes in the industries has been reduced. For instance, one cubic meter of sea water used by an alkali production industry in Qingdao city on the Huanghai (Yellow Sea) shore costs only 0.17 Yuan (about 0.02 U.S. Dollar), making up only 1/4 of the fresh tap water sold by the city's water works. Based on this experience, therefore, sea-water utilization can be employed for solving the problem of high consumption of cooling water in industries in terms of allocating and reallocating (adjusting) these industries' location distribution along the coastal zones, so that we can make fuller use of sea-water. In addition, there will be a good prospective for developing desalination of sea-water with a progress in technology.

Besides, China has wide areas of brackish water reserved in shallow aquifers as groundwater and in some lakes as surface water. Taking the example of the North China Plain, the brackish water reserved in the plain totals 5,800 million cubic meters or so, which has a salt content between 2-5g/l. This also offers great good potential for water development.

(5) Recycling, Reuse, Recharge, Regulation and Reallocation

There are " 5 R " suggested to rationally utilize water resources. The first "2 R" means treating wasted water and reusing it. The "3rd R" is to replenish groundwater and surface water bodies. The "4th R" represents regulating water regime against unevenness in temporal distribution of water. The "5th R" is to reallocating water against unevenness in spatial distribution of water.

The unevenness of China's water resources is a reason for consideration in the water transfer projects to improve such highly uneven distribution. A prerequisite for implementing water transfer must be based on a water saving basis. This is the basic principle of any area reallocation of regional water. In most cases of planned water transfer project in China, importing water is supplementary to the local water system. Obviously, the most economical and most rational water transfer project will be achieved on the basis of establishing a water saving system and of fully creating a potential capacity of local water resources in water importing region.

Acknowledgement: The research is partly support by Key program of Chinese academy of Sciences, KZ: 951-A1-203.

References

1. Changming Liu and Xiwu He et al, 1996, Strategy on Water Problems in China's 21 thCentury, Science Press, Beijing.

2. Biswas, A. K. Water for Sustainable Development in the Twenty-first Century: In: Biswas et al ed. A global perspective, water for sustainable development in the 21st century. Oxford University Press, Delhi, 1993, pp7-17.

3. Changming Liu, Maozheng You. South-to-North Water Transfers and Sustainable Agricultural Development. Eco-Agricultural Research, 1993, Vol. 1, No. 1, pp45-49(in Chinese).

4. Changming Liu et al. Strategies for China's Water problems in 21st century. Beijing: Science Press, 1996.

5. Hydrological Bureau, Ministry of Hydrological Engineering and Hydropower. Assessment of China's Water Resources. Beijing: Hydraulic Engineering and Hydropower Press, 1987.

6. Changming Liu et al. Rainwater Catchment Systems in North China. Journal of International Rainwater Catchment Systems, 1983, Vol. 1, No. 1, pp37-40.

Ecological concern with water-related disasters Lessons from Flood of the Yangtze River in 1998

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Abstract: Extremely heavy flood of the Yangtze River in 1998 has caused great damage and concern of the whole country. This paper intends to give a general analysis about the causes of the flood and the strategy for restoration of degraded ecosystems. It was discovered that the flood of 1998 was caused both by natural factors as well as by unreasonable human activities including deforestation, overgrazing, sloping cultivation, reclamation of lake for agricultural cultivation etc. A series of measures for ecological restoration were suggested. These include to: carry out integrated survey and assessment of land cover and land use in the watershed of the Yangtze River; establish overall plan for ecological restoration under the general framework of sustainable development of the watershed; restoration of ecosystems by preservation of natural forest in the upper reaches of the river; closing hills for natural regeneration; establish shelter belt systems, development of no-wood production; conservation of grassland ecosystems in high altitude, dry habitat, and difficult for afforestation areas etc.

China is one of the countries in the world, which suffers most seriously from natural disasters. Over the past forty years, flood caused a great deal of economic losses with death tolls averaging thousands each year. Economic development, population growth, and ecological degradation, especially in high-risk areas, where there is high population density and intensive production, have led to an escalation in the frequency, extent of effect and degree of risks of natural disasters. In some regions, these factors are seriously hampering long-term efforts to eradicate poverty.

The flood of the Yangtze River in 1998 was caused both by human activities and by natural factors. Climate abnormality and the influence of geological and landform factors are the natural factors. While in the human factors, there are both engineering problems and the consequence of environmental destruction.

1. Fragile environment and climate abnormality are natural factors resulting flood

(1) Abundant rainfall with uneven distribution in the Yangtze River Basin.

The Yangtze river is the longest river in China, having many tributaries that form a vast drainage system. Ten tributaries each have an annual mean flow of more than 1,000 m^3/sec. The Yangtze River basin lies in the subtropical monsoon region of China. The precipitation is abundant and the distribution of it is uneven. 80% of the rainfall is concentrated in August and September. The water in Yangtze river comes mainly from its upper reaches, which account for more than 90% of its total runoff. The biggest flow occurs in summer, sometimes early and sometimes late, depending on when the summer monsoons move northward. Roughly speaking, the earliest flood comes from the Dongting Lake drainage system, then from the main stream of the Yangtze west of Yichang and last from Hanjiang river. If the high water from the main stream and its tributaries arrives at the sometime, the flood may occurred, presenting a big big menace to land areas along the middle reaches of the Yangtze River. Due to the influence of phenomena of Elneno and Nolina. in Summer of 1998 the worse situation occurred. `Flood in upper and middle tributaries met together and the flood peak occurred repeatedly. This is an important climatic factor resulting in flood.

(2) The land form and the relief as well as the fragile environment of the upper reach of the Yangtze River accelerate soil erosion process.

In the upper reaches, the landform mainly consists of high mountains with deeply dissected valleys. In the fragile environment, in conflict with gravity and geologically tectonic movement, the upper reaches is the area where earthquake, landslide, and debris flow frequently takes place. It is also the most severe area of soil erosion. When the river runs through the Three Gorges, the river gradient ratio is fairly low so that sediment is deposited and water flow is blocked.

2. Excessive cultivation of lake and construction in flood-diversion and flood storage areas

Decades ago, a series of flood-diversion areas and water storage areas were planned and constructed. These infrastructure engineering had played important role in mitigation flood in 1954, when the flood was as much as it was in 1998. However, due to population growth and economic development, these flood waterway and flood-diversion areas were not only cultivated but also was occupied by many permanent buildings, factories and project facilities. It can not be used for mitigating the flood function. If during the flood season in 1998 the waterways were used for flood discharge, a great deal of economic loss will definitely be resulted in. That is why the central government had to decide to fight against flood and tried the best to reduce the loss from flood discharge. This was resulted to raise the level of flood and a high risk was faced during 1998. Thanks to the heroic spirit and joint efforts of millions army and people we created historical miracle had won the flood control in 1998. However, this also lift us a deep lesson and experiences for future flood control

3. Unreasonable land use accelerating the violence of flood disaster

(1) Illegal cutting and deforestation

Forests play an important role in conserving water and regulating runoff. Forests take the advantage of multiple vertical structure to intercept rainfall, redistribute rainwater and weaken soil erosion to ground soil. But the function of conserving water is quite different in different kinds of forest stands. Human-destroyed, low-aged artificial forests have low growth rate and low capacity of keeping water and conserving soil. China's forest resources are mainly distributed in Northern China and Southwestern China, just located in the areas, in which severe flood disaster occurred in 1998, of the upper and middle reaches of the Yangtze River and the Songhuajiang River. For a long time, these areas were the major ones for timber logging and producing. Forest resources have been destroyed severely. In 1960s, the policy of building industry in remote mountain areas aggravated deforestation in natural forest areas. Now the area and stock volume of forest resource reduce 50% compared to that of 1950s. For example, more than 50 counties in the upper reaches of the Yangtze River have forest coverage less than 3% - 5%. Some forest enterprises have no forest resources for logging.

(2) Unreasonable exploitation of wetland and lakes, including drainage, enclosing cultivation and reclamation

Wetland, including lakes, marshes, turf, coastal belts, mangroves and coral reefs, is water sink and water regulation pool. Wetland plays an important role in flood storage and drainage, watershed water balance, and pollutant decomposition, so enjoying the good fame of "Kidney of the Earth". There is 25 million hm^2 of wetland in China, accounting for 2.6% of the total territory area, now almost degraded. The lakes in the 500 km length of reaches from Zhicheng to Wuhan were almost enclosed for cultivation. The capacity of flood regulation and storage has been weakened greatly. For example, Dongting Lake is the only one having good water regulating and storage capacity. The area of lake region shrank from 4350 km^2 in 1949 to 2691 km^2 in 1978 and water capacity decreased from 29.3 billion in 1949 to 17.4 billion in 1978, reducing 38.2% and 40.6% respectively. On the average, the bottom of lake rose 3.6 cm per year, and the area of beaches amounted to 120000 hm^2, with 666.7 hm^2 of annual expanding speed. Under the condition of enclosure for cultivation and sand deposition, the loss of water capacity occupied 1/5 of the total. This enhanced threats of flood.

(3) Irrational cultivation on purpose to excessively pursuing food production

The Sichuan branch of the upper reaches of the Yangtze River is an agricultural region where rural population accounts for 85.6 percent of the local total. In the region cultivation is intense. For example, in western Sichuan Province, the landform is mainly composed of high mountains and steep slopes. Local residents have to cultivate along riversides. In the upper reaches of the Yangtze River, 70% of the arable land is cultivated without any measures of soil conservation. Furthermore, slope lands over 25 degree are commonly cultivated.

4. Strategy and measures for prevention and mitigation of flood

In order to relieve the Yangtze flood menace, large-scale work has been done since 50s to control the river. Great achievements have been made along its course in flood prevention, irrigation, power generation and navigation. Dikes along its main streams and its main tributaries have been repaired, raised or strengthened. The Jingjiang flood-diversion project, the Hanjiang flood diversion project and other flood-storage projects have been built along its middle reaches, the area usually hit by unusual floods. Many lakes have been dredged, and some bending in the river course has been straightened. All of these provide an important basis for further work in protection against disasters, in mitigating their effects and in increasing capability to preventing flood.

For further preventing and mitigating floods a complex of measures should be taken. This include: promoting the establishment of flood prevention and mitigation systems, improving flood control management, and reducing floods caused or aggravated by human factors

(1) A. Promoting the Establishment of flood Prevention and Mitigation Systems

Flood management involves a combination of activities, including legislation, planning, organization, coordination, intervention and engineering, which are carried out by the government, appropriate agencies and social organizations for the prevention and mitigation of disaster. This is at the core of the disaster mitigation system, and permeates all actions associated with it.

(2) Comprehensive planing

Establish an overall plan for flood control based on sustainable development principles. to make an overall plan for the whole river watershed as a integrated system combine enginering with vegetative measures. and take the whole ecosystem into consideration in terms of natural, ecological and economic aspects. Manage the whole ecosystem and regulate in macro-scale. In the near future, the mechanism of section management should be changed and establish a institution of watershed management and comprehensive regulation to coordinate and supervisor key ecological construction and water conservancy construction.

(3) Implementing comprehensive watershed management

Taking watershed as a unit, and combining environment protection with economic development to carry out vertical planning and comprehensive development is one of the successful experiences in the field of mountain ecosystem restoration and management. It is also the research objective of landscape ecology. This experience should be promoted the rehabilitation and restoration in mountain ecosystems.

(4) Withdrawing unsuitable cultivated land for reforestation and lake

The key to stopping cultivation for reforestation and lake is to arrange the surplus manpower to service and processing industry and settle the problem of food supply for them. In the place where slope more than 25, cultivation should be forbidden. The cultivated land should be withdrawn as soon as possible for afforestation. In the moderate slopes where soil and water conditions are better, the land should be planned comprehensively and agroforestry should be promoted. The natural beaches should be controlled strictly for cultivation in order to maintain its function of regulating and storing floodwater.

(5) developing rangeland for animal husbandry

In the areas of slope mountains and alpine meadows, and in the arid valleys, rangeland should be developed for animal husbandry. It is an effective way to shake off poverty and promote sustainable development.

(6) **strengthening forestry reconstruction**

The forest resources are mainly distributed in Northeast and Southwestern China, in the upper and middle reaches of the river in which flood occurred. The forest resources are destroyed severely due to more deforestation and low conservation. So the following suggestion should be attached more attention:

Intensifying natural forest conservation: There is plenty of biodiversity in natural forest. The natural forests play an important role in conserving water, soil and sustaining ecological balance. It is the precious treasure of China. Natural forest resources are now limited, especially in the upper reaches and along riversides in huge rivers, the natural forests should be protected as water conserving forests. Natural forests should be categorized to manage according to scientific classification. I suggest that permanent water conserving areas should be established in the river banks in the extent of 10 km and ban for deforestation.

Closing hills for natural regeneration and transforming secondary forests: Closing hills for natural regeneration is an effective measure for mountain greening. This measure should attach more attention on closing hills and in combination with management and fostering young trees. The air-seeding forests and young forests in fragile area should be strictly closed and prevent destruction from animal and human activities.

Encouraging public greening projects: In the areas of difficult to restore vegetation, such as limestone mountains, red soil hills and sandy areas, more investment should be input to ensure vegetation restoration. In areas with deep soil layer and withdrawing cultivation for afforestation, economic forests can be afforested. In economic forests with low benefit of protection, biological hedgerows should be combined to enhance the benefit. The afforested species should be deep-rooted, flourishing-branched, fast sprouting and fast-grown and productive trees. The shelter belts should be multi-functional mixed forests.

Enhancing investment and expanding money-raising channels: In addition to the investment from central government and local institutions, more channels should be expanded to attract financial support. Ecological compensatory mechanism should be established to meet the need of afforesting commonwealth forests.

Seeking after new management mechanisms.

Boosting legislation and enhancing publicity of forest conservation.

(7) Promoting wetland conservation and rational utilization

The status and tendency of wetland degradation should be quickly investigated and ecologically evaluated. This is the basis for finding sustainable utilization models and bringing the role of flood peak reduction, water storage and runoff regulation into full use.

(8) Establishing eco-economic accounting system and ecological benefit compensatory system

Now the State Council is formulating forest accounting and forest benefit compensation mechanism. This is not only beneficial to enhance the enthusiasm of managers but also a new conception for benefit evaluation.

(9) Carrying out education of laws and regulations and improving environmental consciousness

Legislation and related regulations should be consummated, execute the law and boost propaganda in order to publicize the consciousness of environment protection. Natural forests should be protected strictly and ensure the forest resources in the upper reaches of large rivers not to be destroyed.

(10) Reinforcing scientific research and technology application

Summarize and promote scientific achievements for demonstration. As regard to resource protection and scientific and technological issues, especially watershed sustainable development, ecosystem ecological service and watershed management models and its evaluation, resource accounting and management techniques of water and conserving forests, should be the key points of research project. Dynamic remote sensing system on the base of land use and geographical information in the Yangtze River should be established to build up database and monitoring systems in order to forecast storm and flood.

Irrigation in China's Agriculture: Critical Institutional Challenges

Richard Reidinger
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1. Introduction

Four key issues facing the water resources sector in China are floods, water scarcity, food security, and pollution. Irrigation and drainage are related to all four issues, which are well known, generally agreed, and not unique to China. China has spent many billions of RMB on structures and hardware solutions aimed at these problems. Such investments have produced large benefits, but the issues remain and in some ways are growing worse. Heavy investment in physical works has not solved the problems.

2. Better Water Management through Institutional Development

What is needed now is to improve the management of water resources at both the macro and micro levels, and that will require increased investment in institutional development in the broadest sense. Institutional development should go beyond the traditional narrow concept of organizational and manpower strengthening and training, to encompass development and change of the institutional system and framework for management. Compared to costs for physical infrastructure, costs for institutional development would normally be relatively small, sometimes requiring only the stroke of a pen. But it may in fact be more difficult to implement compared to construction of physical facilities, and traditionally water resource investments have instead focused mainly on physical works rather than institutional development. Institutional "software," however, deserves equal attention with physical "hardware," for the institutions and the institutional framework determine the effectiveness and benefits of the huge hardware investments. Key institutional development problems at the macro or national level are closely related to problems with water resource management and irrigation at the micro level.

3. Macro-level Water Resource Management

River Basin Management. At the macro level, for example, is the well-know institutional issue of river basin management. The seven river basin commissions have relatively little actual power to deal with the issues, do not control or provide water resource investment allocations in their basins, and have relatively limited financial resources to promote improved water management and policy implementation. The commissions need to develop mechanisms for consultation and decision making with and between the provinces and other stakeholders; they need to be more participatory so that they represent the views and gain the support of the stakeholders concerned, including in particular the provincial governments of the river basins; they need to be given more control over the allocation of water-related financial resources in the river basin; they need more authority for comprehensive, integrated management of the four key water issues above; and they need to be provided with more financial resources and a clear mandate to promote and support improved water polices and management. Alternatively, a new type of river basin management organization may need to be created with these powers, functions and characteristics.

Fragmentation of Responsibility for Water Resources Management. Under the Chinese Water

Law, the Ministry of Water Resources (MWR) is charged with unified administration and management of water resources throughout the China, and a 1998 State Council decree on administrative reorganization of the government consolidated and strengthened MWR's role in water resources management. In practical terms, however, MWR is directly responsible mainly for water resources management and use with regard to irrigation, drainage, and flood control. The Ministry of Construction is responsible for urban water supply and its management, and the State Commission for Economy and Trade is responsible for hydropower construction, although MWR is generally responsible for flood control dams with hydropower. In addition, other ministries and agencies still have linkages with water and water management, such as the Ministry of Agriculture, Ministry of Land and Resources, Ministry of Science and Technology, Ministry of Health (for rural water supply and sanitation), and the State Environmental Protection Administration. In addition, MWR like many other ministries and agencies in China is vertically integrated, with their line offices generally extending down to the municipality or county level or lower. For these lower levels, however, MWR's influence is generally limited to technical guidance; administrative responsibility for local water resource management resides with the local government. Fragmentation of water resources management in China exists between the various agencies at all levels, from the top down. Such problems are not unique to China, and may be unavoidable. Institutional mechanisms, such as Water Resources Councils, are needed at the central level and lower levels to help guide and coordinate the ministries and agencies concerned, and to unify water resources management.

4. Micro-level Irrigation Management

At the micro level are the users of water - irrigation, municipalities and industry, plus water needed for environmental purposes. Irrigation is by far the biggest user, although municipal and industrial use is growing rapidly in many areas. However, irrigation generally suffers from both poor infrastructure and weak management and financing, and overall irrigation production efficiencies are relatively low. Even in the water-short North China Plain, farmers produce on average only about 0.85 kg of grain per cubic meter of irrigation water, compared to over 2 kg in the US. There is much room for improvement. But again, this cannot be achieved through improvement of hardware alone, but rather requires improved institutions and management. The challenge is how to increase production per unit of water.

Institutional Issues in Irrigation. The list of institutional issues facing irrigation is obvious and daunting. Water prices are too low to cover the costs of water, leading to inadequate maintenance and degradation of the irrigation systems. Water charges collected are often used for purposes other than irrigation operation and maintenance, which discourages payment of water charges and contributes to inadequate maintenance. Management of large irrigation systems is fragmented between government administrative units, rather than being unified on the basis of hydraulic units which is necessary for high system delivery efficiencies. Water charges levied on a per hectare basis discourage efficient water use by farmers, leading to much absolute waste of water. Lack of water measurement at or near the farm level in canal systems makes it impossible to charge for water by volume, which would promote more efficient use of water by farmers. Inadequate farmer participation and "ownership" contributes to low irrigation management efficiency, high levels of conflict among water users, and low water charge collections. Lack of legal and quantitative rights to use water creates insecurity for water users, which discourages farmer investment in more efficient technology and water management. Lack of effective water licensing and abstraction control allows unrestricted use of groundwater in water-short areas, which has contributed to water shortages and the widespread drawdown of groundwater in the North China Plain. Without better management, even potentially more efficient modern technologies will not achieve real their intended objective of real water savings; for example, modern sprinkler systems without good management can lead to high levels of non-beneficial evaporation and real water waste.

A New Institutional Framework for Irrigation System Management. To resolve the above institutional issues, a comprehensive institutional framework for management if irrigation systems is needed for both the main canal system level and the minor system level. Engineering solutions can contribute, but in general they are not the solution. An example of recent institutional development for better management of irrigation in China are the Self-financing Irrigation and Drainage Districts, or SIDDs, which are currently under pilot operation in eight provinces. The SIDD concept or system deals with most of the issues listed above, and has been developed in China to match Chinese conditions. The SIDD system is designed to incorporate and implement Chinese policies, such as the "user pays" principle, treatment of water as a commodity, water charges to cover costs, water charges according to volume used to encourage efficient use, and direct participation and self-management by water users.

The SIDD system comprises two parts: Water User Associations (WUAs) established by the farmers to take over operation and maintenance of the minor irrigation distribution network and the lower end of the systems usually up to the lateral head; and Water Supply Corporations (WSCs) to take over operation and management of the main canal systems down to the lateral head. Under the SIDD system, the WSC measures and sells water volumetrically to the WUA at the WUA headgate (usually at the lateral head), and the WUA pays according to the number of cubic meters used. WUAs are registered as a legal person with the support of the local government, and WSCs are chartered under the Companies Law. Water deliveries to the WUAs by the WSC are governed by water sales agreements between the two parties which specify the rights and responsibilities of both. Because water deliveries are charged volumetrically, WUA farmers have a strong incentive to use water more efficiently and reduce waste. WUAs collect water charges from their member farmers, and purchase water by the cubic meter from WSCs on behalf of their members. To date, the results of SIDD pilot projects have been very positive, generally with increased production, reduced water waste, increased water charge collections, reduction or elimination of water conflicts among farmers, and increased "ownership," participation and contribution by farmers. Farmers are generally well satisfied with SIDDs because of the large benefits produced, and local governments usually find their irrigation-related burdens are reduced. To help promote further SIDD and similar reforms, an improved legal framework and high-level policy and budget support is needed.

Integrated Package of Practices for Irrigated Agriculture. Integration of engineering, agriculture and management methods as a package is needed to improve the production and water use efficiency of irrigation, and to do this will require institutional development. Without such integration, engineering measures such as sprinklers and low pressure pipelines may not give the benefits expected, and in some cases may lead to adverse impacts such as increased real water consumption rather than water saving. When integrated with improved agricultural practices by farmers, such as better fertilizer and seeds and better on-farm irrigation management through scientific irrigation scheduling, however, irrigation technology investments can yield far higher returns. Indeed, the effective integration of engineering, agriculture and management frequently determines whether investments in improved irrigation are financially viable or not. Moreover, raising yields through better irrigation management methods such as irrigation scheduling and better agriculture practices such as plastic mulch can also provide substantial real water savings through reduction in non-beneficial evapo-transpiration; such water savings are often more certain than with irrigation investments alone. To achieve integration of these three methods, however, will require institutional development and changes to coordinate and ensure closer cooperation of the agencies required for their delivery, and to deliver the three methods to the farmer as a package.

Filling the Agricultural Engineering Gap. To implement the type of irrigation reforms indicated above, development of a new, specialized cadre or discipline engineers is needed in China. This could be a specialized engineer whose primary focus and skills (for irrigation) would be on linking the irrigation source to the farmer, efficient use of water on-farm, support of farmer organizations for better irrigation management, and the provision of the integrated package of irrigation technology, agricultural practices, and management. At present there is often a gap in the expertise available in the field, between for example, the agronomist and the irrigation or civil engineer. Generally, neither is an expert on the field installation and efficient operation of specific modern irrigation technologies such as sprinkler and drip irrigation, is specialized in how to increase on-farm efficiency of water use, is well-versed in working with farmers to improve the installation and management of on-farm irrigation through scientific irrigation scheduling and management practices, or is specially trained to work directly with farmer groups in support of SIDDs and other changes in the institutional framework. In the US and Europe, this gap is generally filled by the discipline of "agricultural engineering." This gap in skills and expertise will need to be filled through both development of new, specialized training programs for engineers, and provision of agricultural engineering employment positions in the concerned agencies. Development of this new cadre will also require cooperation between the technical line agency disciplines of irrigation and agriculture.

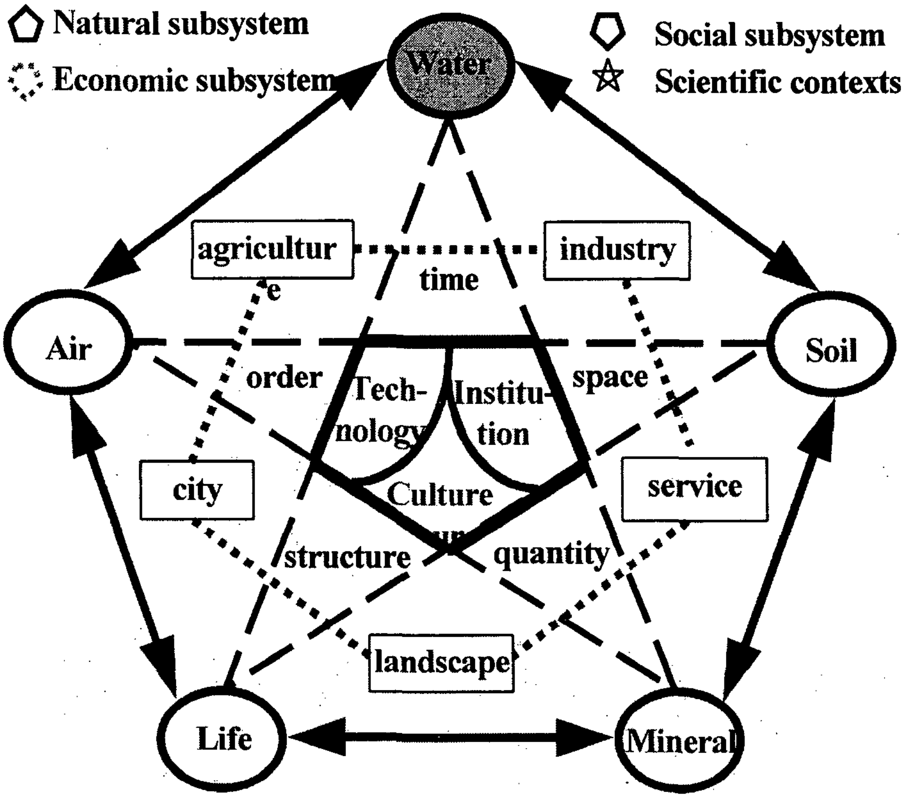
5. Summary and Conclusions

China, like many other countries, faces four key water resource issues - floods, water scarcity, food security and pollution. Irrigation and drainage are related to all four issues. Despite heavy spending for "hardware" to deal with these issues in China, they remain serious and in some ways are growing worse. The critical missing ingredient for handling these issues more effectively is institutional change and development in the broadest sense; this is necessary to improve water management at both macro and micro levels. Increased high-level policy support and investment for institutional development to improve "software" in the water resources sector is needed. At the macro level, the overriding institutional issues concern river basin management and fragmentation of responsibility for water resources management. At the micro level for irrigation and water management, key institutional issues concern institutional development for efficient self-financing and self-management of irrigation and drainage based on farmer participation such as SIDDs, provision to farmers of engineering, agriculture and management methods for improved irrigation as an integrated package, and filling the agricultural engineering skills gap.

CHINA WATER VISION

The Eco-sphere of Water, Environment, Life, Economy & Society

(Executive Summary)



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Chinese Academy of Sciences

China Water Vision

(Executive Summary)

Rapid industrialization and urbanization is taking place in China since it opened to the world and began the transition from a planned to a market economy. The pace, depth, and magnitude of this transition, while bringing prosperity and hope to many citizens, has exerted severe ecological stresses on both local living conditions and regional ecosystems. During the past 20 years, both the GNP of industry and the number of cities and towns has increased by three times. Nearly every kind of environmental problem seen in early-industrialized countries and the ecological deterioration seen in developing countries has emerged in China. These have exerted a heavy impact on people's health and the local and regional life support ecosystem. The high pressure of population growth, rapid economic development, and a strong desire to improve life quality, fragmented institutions, low eco-awareness in policy making are threatening both water availability and security.

Water sustainability can only be assured with a human-ecological understanding of the complex interaction of environmental, economic and social/cultural factors and with comprehensive planning and management grounded on ecological principles. In dealing with the fatal issue, a transition from physical engineering to ecological engineering, from reductionism to holism, and from man domination to man-nature harmonization is needed. Therefore, increasing people's understanding of the eco-sphere of "the man-water complex", probing the scientific mechanisms and methods for addressing water problems, and searching for effective technological instruments for sustainable water use are to be considered the keys to China's sustainable development.

Resulting from the severe water stresses from the Yangtze River Basin flooding in 1998, Yellow River Basin water shortage, and heavy pollution of three lakes (Taihu, Dianchi and Chaohu) and three rivers (Huaihe, Haihe and Liaohe), experts and decision makers in China have given much more attention to water issues in recent years. A series of meetings and workshops on water issues have been organized by the project team together with the relevant agencies in China. Issues discussed include water states (quantity and quality), water stresses (flooding, drought, eutrophication, desertification, ground subsidence), water security (on food, health, biodiversity, economy and society), water systems (water-man complex social-economic-natural ecosystem combining production, consumption and natural service) and water strategies (from technological innovation, institutional reform and behavioral inducement). Some important scientific issues and priorities for the water system, for the next 25 years were identified.

This report is a preliminary result of China's water vision compiled by researchers from the Chinese Academy of Sciences and consultation with experts from all over China. It is partly supported by the World Water Vision through UNESCO. Our special gratitude goes to Dr. Frank Rijsberman, for without his help, this report would not be possible now.

1. Water States

China has abundant water resources. There are more than 1,500 catchments each with an area larger than 1,000 km^2. The total annual runoff of all rivers in China is estimated to be more than 2,700 billion m^3. The annual replenishment of groundwater is estimated at about 800 billion m^3. After correcting for overlapping calculations of river runoff and shallow groundwater, the total amount of surface water and groundwater resources is around 2,800 billion m^3, which ranks China the sixth largest in the world. There are 17 major rivers each with an annual runoff exceeding 50 billion m^3 and 130 lakes each with surface area exceeding 100 km^2.

China has the largest population in the world, 1.24 billion in 1997. The amount of runoff per capita is around 2240 m^3, which is about 29% of the world's average and ranks among the lowest in the world. The amount of runoff per hectare is 2930 m^3. With 7% of the world's total fresh water resources, China has to support more than 21% of the world's population. During the past 50 years, the population of China has doubled, while the water use for human purposes has multiplied by 5.5 times.

The main characteristics of the water issues in China are extraordinary uneven geographical distribution. 85% of the water is located in the Yangtze River basin and its southern area (15 south provinces), which accounts for only 55% of the total population and 41% of the total land. The per capita water availability in southern China is 5 times more than that of northern China, and its per hectares water resource is some nine times greater. In Southern China, 60% of the annual precipitation is in April to July, and 80% of the annual precipitation in Northern China is in July to September. The per capita available water in Huaihe, Haihe and Yellow River basins is below 1000 m^3, the internationally accepted definition of water scarcity. The runoff in the Haihe river basin, for example, is particularly low, being only 245 m^3 per capita (Fig.1).

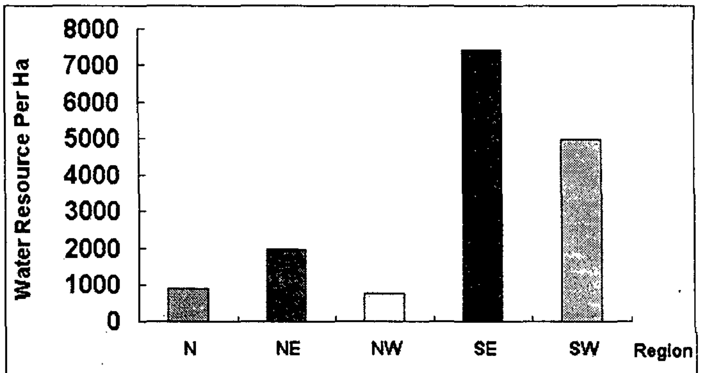

Fig.1 Water Resources Per Ha in Different Regions

The water for nature service in northern China is too far away from nature's need. In 15 of northern China's provinces, the available water per hectare of the total land is only 962 m^3. While in 15 southern China's provinces, it is 5752 m^3, 5 times higher than that of the north. This explains why water shortage is one of the main factors for the weak function of nature service in north. If we take 1465 m^3 per ha, 50% of the average level of water availability in China, as the minimum demand for maintaining the nature service function in northern China, we need at least 829.5 billion m^3 water, which is 2.1 times of the current available water resource in 15 of northern China's provinces.

On average, per $10^4 m^3$ water resource serves 4.46 people in China. According to this figure, the water resource in 7 of North China's provinces (around $168.5*10^9 m^3$) can only serve $75*10^6$ people, which is only 23% of the current population. Or the carrying capacity of water has been overloaded by 4 times' human activities. In the North China region, 95% of water resources that at available are being used, while in the southwest region, only 6% of the resource used.

2. Water Stress

The driving forces of the water issue are: high pressure of population growth, rapid economic industrialization and urbanization, a strong desire to improve life quality, fragmented institutions, low eco-awareness in policy making which threaten both water quantity and quality. The inappropriate use of water has caused severe qualitative and quantitative water shortages. The unusual hydrological and inappropriate anthropological processes have resulted in the acceleration of flooding and drought, desertification, soil erosion, biodiversity loss, and service function declination.

The agricultural water consumption in 1949 was $1,001 \times 10^8$ m^3, in 1965 it was $2,545 \times 10^8$ m^3, in 1980 it was $4,195 \times 10^8$ m^3 , and in 1997 it was $3,920 \times 10^8$ m^3, accounting for 97.1%, 92.7%, 88%, and 70.4% of the total water use. In the past 50 years, agricultural, industrial and domestic water consumption has increased by 4, 47 and 42 times respectively.

The agricultural water use efficiency on average in China is about 0.4~0.5. In northern China, for example, the irrigation quota is 7,500~12,000m^3/ha, 2~5 times greater than that of actual crop needs. If the average efficiency raises to 0.65 through some technological measures, reaching the level of some advanced areas in China, 130 billion m^3 of water could be saved every year for the same area.

Irrigation works in China were mostly built in 1950s~1990s, and have been in use for 30~40 years. For a long time, the works have deteriorated due to lack of maintenance. Of all large and medium reservoirs, three fourths are dangerous and the sedimentation is very severe. According to an investigation of 231 large reservoirs, for example, the average annual sedimentation rate is 2.3%, and the cumulative sediment takes 14.3% of the total capacity.

In 1997, the total drainage of waste water was 564×10^8 m^3, of which 68% was industrial and 32% was domestic sewage. At present, the urban domestic sewage treatment ratio is only 13.6%, so sewage is discharged directly to rivers and lakes without any treatment. The industrial sewage treatment ratio from prefectural or above factories is 84.7%, but the reusing ratio of sewage is only 5%. Furthermore, the increasing use of chemical fertilizer and pesticide, the raising of livestock and the heavy polluted rural industries have accelerated water pollution and ecosystem deterioration causing the non-point source pollution which accounts for 70% of the total pollution load of China's water courses. According to an evaluation of the water quality of rivers, only 32.8% could meet the EPA standard of grade I and II, with 23.6% in grade III, and 27.7% in grade IV and V.

The excessive exploitation of groundwater has caused a reduction in the level of the water table, land subsidence and sea water intrusion. There are more than 50 cities in which land subsidence has occurred, 700 land subsidence sites and 3×10^4 land subsidence tunnels.

The fragmentation of the water management institutions: the Ministry of Hydraulic Engineering takes charge of surface water and flooding control; the Ministry of Geology and Minerals is in charge of groundwater; the Ministry of Construction in charge of the urban water supply and drainage; the Bureau of Environmental Protection in charge of wastewater discharge and water quality protection; and the Ministry of Agriculture in charge of agricultural water use. There are no integrative institutions for the management of the water system.

There are 7.9 million factories in China. In 1997, the total amount of industrial wastewater discharged in China was 22.7×10^9 tons. Industries at the county level and above discharged 18.8×10^9 tons, while town and village industry discharged 3.9×10^9 tons. The ratio of wastewater discharged meeting quality standards from county level or above is 61.8%.

The urban drink of water is taken from rivers, lakes or reservoirs, of which 90% are polluted. And another 145 million citizens in small towns have no access to a safe water supply.

Regional water stresses (Fig.2):

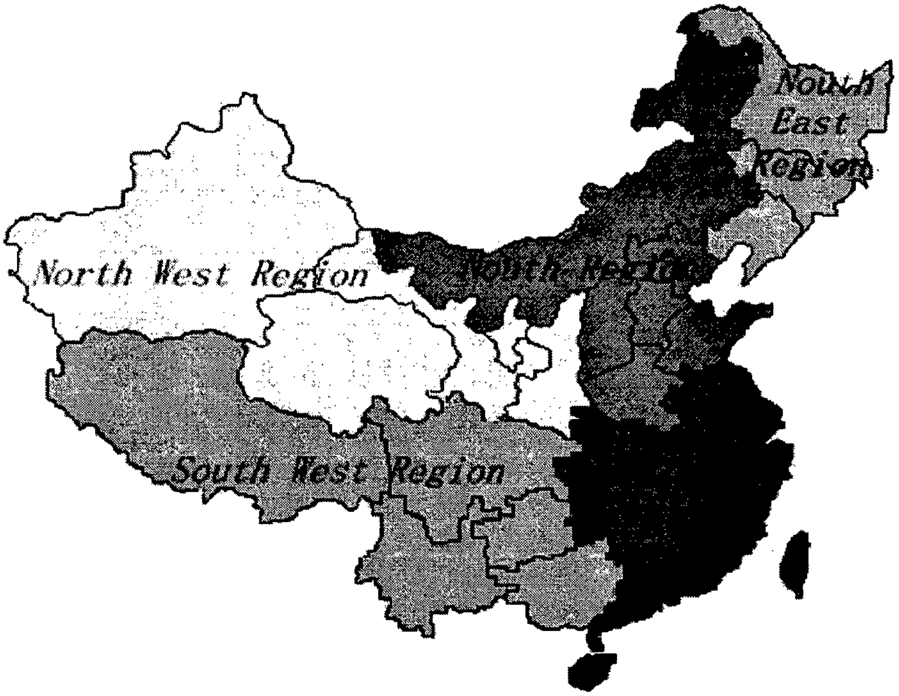

Fig 2 Water resource regions in China

(1) North China (7 provinces: Iner-mongolia, Hebei, Beijing, Tianjin, Shanxi, Henan and Shandong):

severe water shortage for production and municipal use, over-withdraw of ground water, intensive mining, ecosystem deterioration, and heavy urban and industrial development. The total water resources is about $168.5\times10^9 m^3$. The average amount of water resource per capita and per hectares is 522 m^3 and 911 m^3 respectively. The exploitation ratios of surface water and groundwater in 1997 were 66.8% and 78.9% respectively with 75.2% of the water being used for agriculture, 14.6% for industry and 10.2% for domestic use.

(2) Northwest China (5 provinces: Xingjiang, Ganshu, Ningxia, Qinghai, Shanxi):

severe water shortage for nature service, over-exploitation of the watershed which caused severe desertification and soil erosion, over-construction of water-projects, low efficiency of irrigation and a positive feedback of poverty-overexploitation-severe poverty. The total water resource is about $2235.1\times10^8 m^3$. The average amount of water resource per capita and per hectares is 2507m^3 and 739 m^3 respectively. The exploitation ratios of surface water and groundwater in 1997 were 36% and 12.6% respectively with 89.8% of the water being used in agriculture, 6.9% for industry and 3.3% for domestic use.

(3) Northeast China (3 provinces: Liaoning, Jining, Heilongjiang):

overloaded heavy industries, over exploitation of wetlands and forests, and heavy water pollution. The total water resources is about $1529.0\times10^8 m^3$. The average amount of water resource per capita and per hectares is 1465 m^3 and 1942m^3 respectively. The exploitation ratios of surface water and groundwater in 1997 was 29.8% and 52.5% respectively with 69.5% of the water being used in agriculture, 22.5% for industry and 8% for domestic use.

(4) Southeast China (11 provinces: Shanghai, Jiangsu, Zhejiang, Fujian, Anhui, Jiangxi, Hunan, Hubei, Hongkong, Guangdong & Hianan):

highest population density, over-growth of regional urbanization, rural industrialization and intensive petroleum-agriculture which caused severe water pollution and health problems, and therefore a quality-induced water shortage; Frequent flooding and drought; The total water resources is about 9259.2×10^8 m^3. The average amount of water resource per capita and per hectares is 1987 m^3 and 7410 m^3 respectively. The exploitation ratios of surface water and groundwater in 1997 were 25.3% and 4.8% respectively with 64.2% of the water being used in agriculture, 25.5% for industry and 10.3% for domestic use.

(5) Southwest China (5 provinces: Sichuan, Chongqing, Yunnan, Guizhou, Guangxi, Xizhang):

deforestation and inappropriate land reclamation on steep land and a fragile ecosystem, a backward transportation infrastructure, rich water resources and hydropower potentials. The total water resources is about 12751.8×10^8 m^3. The average amount of water resource per capita and per hectares is 5384m^3 and 4948m^3 respectively. The exploitation ratios of surface water and groundwater in 1997 were 6% and 1.1% respectively with 66.1% of the water being used in agriculture, 21.2% for industry and 12.7% for domestic use.

3. Water System

A water-centered eco-sphere is a kind of artificial ecosystem dominated by technological and social behaviour, sustained by natural life support system, and vitalised by ecological processes. It was named by S.Ma as a Social-Economic-Natural Complex Ecosystem. The material metabolism through human society is just within the "five-element" flow between water and soil, wood, metal and fire. Where the flow is blocked or deteriorated, there is problem (See the Figure in the cover page).

The water-ecosphere is driven by four fundamental forces: energy (physical agent), money (economic agent), power (institutional agent) and spirit (cultural agent). Water could also generate or stimulate energy, money/wealth, power/governance and spirit/culture and their interwoven products namely human society.

Man is the key constructive and destructive agent in the water issues of China. It drives its positive and negative feedback through competition for water efficiency, symbiosis for water equity and self-reliance for water sustainability.

(1) Poverty is the most acute driving force of water problems. The positive feedback is exaggerating the loop of "poverty -- overexploitation -- ecosystem deterioration -- severe poverty".

(2) The long tradition of water saving and conservation in China based on Daoli, Shili, Qingli, Five-Elements, Ying and Yang, and Feng-Shui theory (wind and water).

4. Water Scenarios

(1) Business As Usual Scenario (BAU):

(3) The economy of China will develop greatly during the next 25-30 years: the total GDP, the industry output value and the grain yield in 2025 will be 6.1, 7.7 and 1.3 times that of 1997 respectively.

(4) Population growth is a critical factor with regard to water demand. It will keep on increasing to 1.54 billion by 2025. In the mean time, nearly one half of the population will be living in cities and towns with the urbanization ratio moving from 29.2% in 1997 to 48.8% in 2025.

(5) The cultivated land in China will be about 91 million ha in 2025, which is about 3.91 million ha less than the current cultivated land. In the meantime, the irrigation area will be about 56.34 million ha in 2025, increased by 19.8%. By that time, the irrigation area will account for 62% of the total cultivated land, 12% greater than that in 1997.

(6) However, this development will pay the price of an increasing level of water stress and a high degree of vulnerability. Water shortage will be 96.8 billion m^3 and grain shortage 48.1 million tons by 2025, and the supply of water would be most likely the bottleneck during the next two decades in this scenario.

(7) This water shortage will be increasingly severe during the period from 1997 to 2015 as the water demand for economic development exceeds the water supply. However, the stress will slightly improve after 2015 due to significant social, economic, and technical progress.

(8) The agricultural water demand ratio of the total demand will reduce from 70% in 1997 to 53.5% in 2025, though its absolute figure will not significantly change, with only a slight increase of 3.7%, from 421.6 billion m^3 in 1997 to 437.5 billion m^3 in 2025. The demands from industry and domesticity will double in 28 years. The industrial water demand will increase from 126.7 billion m^3 in 1997 to 270.8 billion m^3 in 2025 and the domestic water demand from 53.9 billion m^3 in 1997

to 108.6 billion m^3 in 2025.

(9) Led by the thermal power industry, six industries, including papermaking, chemical, metallurgical, printing and dyeing, and food and drink industries, make a great contribution to excessive water consumption in China. The amount of fresh water used by the thermal power industry, for example, will be about 30 billion tons by 2030. All the six industries will reach their summits and enter their smooth period or withered period for water consumption. However, the ratio of high-water-consumption industries will gradually decline along with industrial transformation in next 25-30 years.

(10) Unless the central and provincial governments take effective measures to keep pace with the carrying capacity of the water resource during rapid industrialization and urbanization, water security and sustainable development in China will be jeopardized.

(11) All the conclusions here are based on an average hydrological regime. If a large-scale disaster in China happens, the water shortage will be critical and the grain yield will fall under the security line with an import ratio larger than 10% of the total grain production.

(2) Towards sustainable Development Scenario (TSD):

(12) The current irrigation efficiency in China is only 40-50% compared to 80-90% in some industrialized countries. If the ratio increases to 65% by 2025, the amount of irrigated land will be increased by 7 million hectares without additional water.

(13) The current ratio of cereal yield to water in China on average is only 1.17 kg/m^3, much less than that of industrialized countries. If it increases to 1.59 kg/m^3 by 2025, which is only 80% of the western countries' current level, 51.8 billion m^3 water could be saved in 2025.

(14) If the annual increase rate of grain yield is changed from 1.3% to 1.5% through various technological and ecological measurements, the grain yield would reach 6639.7 kg/ha and the total grain output will reach 684.36 million tons in 2025.

(15) Compared to developed countries, the water-saving potentials in China is large. The water reuse ratio could be 57.29% and 68.28% in 2010 and 2025 respectively.

(16) If the water consumption coefficient decreases to 25.60 m^3 per 10^4 RMB industrial output in 2025, the industrial water demand will decrease by 44.6 billion m^3.

(17) The irrigation area could be 51.80 and 57.93 million ha in 2010 and 2025 respectively. In this case, the ratio of irrigated land to total arable land are 56% and 64% respectively.

(18) If the proportion of cereal, cash-crop and feed crops is gradually changed from 5:3:2 in 1997 to 4:3:3 in 2010, and 3:3:4 in 2025, and the grain consumption per capita and the grain for industrial use are maintained at the level of 1997, then the grain for feed will increase by 140 million tons. This is equivalent to 45 million tons of extra meat production with an increase of per capita 30kg. Furthermore, there are roughly 400 million hectares of pastures, grasslands and cultivable desert lands in China that are not appropriately exploited or managed (30% of higher quality, 30% of average and 40% of bad quality). Annually 600 million tons of crop stalks/straws and other alternative biomass could be used to substitute for grain in livestock raising and industrial production.

(19) In TSD, the ratio of high-water-consuming industries decreases from 74% in 1997, to 68% in 2010 and 64% in 2025. The industrial water demand will decrease to 203.4 billion m^3 and 236.3 billion m^3 in 2010 and 2025 respectively. That is to say, about 18.5 billion m^3 and 24.5 billion m^3 water could be saved. Then the water use per 10^4 *RMB* industrial output in 2010 and 2025 will decrease to 55.58 m^3 and 27.09 m^3 respectively.

(20) If the structure of domestic livestock is adjusted from grain-fed to herbivorous domination, and alternative protein is produced without consuming so much grain, such as, insects, mushrooms and other micro-organisms, then meat production will increase by fourfold compared with that of 1997.

(21) If the water use quota and reuse ratio is maintained as the same in BAU but the industrial growth rate slows down from 13% in 1997, to 7% in 2010 and to 5% in 2025, then industrial water demand would decrease to 209.7 m^3 in 2010 and to 255.5 m^3 in 2025. That is to say, there could be about 12.2 m^3 and 15.3 m^3 of water saved in 2010 and 2025 respectively. In 2010 and 2025, the corresponding industrial output value would be 34.60 trillion RMB and 82.29 trillion RMB.

(22) In all of the grain production, the proportion of surviving food would reduce slightly, the proportion of feed would be increase, and the proportion of the used grain in industry would decrease too substituted by other kinds of wild bio-mass. According to our estimation, the proportions of food, feed and industrial use are 50%, 30% and 20% respectively at present.

(23) The grain demand per capita will be 428.6 kg and 420.8 kg, and the total grain demand would be 581.5 and 668.9 million tons in 2010 and 2025 respectively. That is to say, about 6.8 and 26.8 million tons grain or about 4.76 billion m^3 and 17.99 billion m^3 water could be saved according to the corresponding grain-water equivalent.

(24) If the domestic water use per capita is 230.0 L/d and 255.3 L/d in urban areas and 100.5 L/d and 122.0 L/d in the countryside in 2010 and 2025 respectively then the domestic water demand will be 74.9 and 105.3 billion m^3. That is to say, about 1.1 billion m^3 and 3.3 billion m^3 of water could be saved.

(25) Water exploitation from other alternative resources, such as salt and rain water, could be 36.1 billion m^3 in 2010 and 59.0 billion m^3 in 2025, and 512.4 billion m^3 and 566.0 billion m^3 could come from surface water in 2010 and 2025 respectively.

(26) Saving one ton of grain is equal to saving 1000 tons of water, and switching 1000 tons of water from agriculture to industry will create 50-70 times more GDP than that from agriculture, at around 50,000 RMB. If 100 million tons of grains saved or substituted, it is equal to tapping 100 billion tons of additional water, and creating 5000 billion RMB of GDP. In the same time, 20 million ha. of cropland or one fifth of the total cropland in China, could be returned to grassland, forestry or wetland, which will significantly enhance the nature service function.

(27) In TSD scenario, we hope to keep three fourths of the total cropland or 100 million ha, the current official statistic figure, for grain production, which is equal to raising the productivity by one third, and to transfer another one fourth or around 30 million ha for other types of bio-mass production, which is more ecologically sound, as is now undergoing in the upper reaches of the Yangtze and Yellow river.

5. Water Security

(28) Compound water security includes food security (food sufficiency and accessibility, food contamination, famine), life security (safe water supply, water-borne diseases, biodiversity conservation), environmental security (environmental pollution, soil erosion, disaster frequency, nature maintenance), economic security (GDP and its increase rate, employment, market prosperity) and social security (water induced social conflicts, water shortage induced outside dependency and water disaster incurred refugee).

(29) Water security in China includes security of food, of life, of the environment, of the ecosystem, economy and society. There are currently 80 million poor people in the countryside, whose income and life condition are bellow the bottom line of the national standard of poverty. Most of these people have no access to safe water, adequate food and a sustainable life supporting environment. The increasing frequency and consequences of flooding and drought in the 1990s are evidence of decreasing water security.

(30) Water is food, water is money, water is protein, water is life and water is spirit. Sustainable development requires maintaining as much as possible increase in all of the following: food, wealth, meat and ecological health. To maintain water security, man has to make trade off between these contradictory goals.

(31) Due to fast economic growth and poor wastewater treatment, the ecosystem, environmental and life securities in BAU will be worst in 2010 and 2025 than in1997 and all will be below the limitations of security. But in TSD, the situation is much improved. Apparently, the security of life, ecosystem and environment resulted from water use are much serious than others and should be paid much attention. The water security in TSD is much better than that of BAU. And, if we take the measures suggested in TSD, almost all of the sub-security indicators are in a sound safety state except the environmental security.

(32) The compound water security issues will become a critical issue in China in 10 years, and will threaten land productivity, food availability and accessibility, human health, nature's service, rural industrialization, regional urbanization, life quality and social stability if appropriate technical, institutional and behavioral measures have not yet been taken. If not appropriately dealt with, they will affect first and foremost newly industrialising regions especially those in rapid social and economic transition, such as in the east coastal areas, the Yangtze River and the Yellow River basins. The level of uncertainty surrounding this issue is moderate. Generally speaking, the social understanding of the water eco-complex is very poor, and little fundamental research has been done so the general data that is available is unreliable.

(33) But on the other hand, China has a long tradition of human ecological thought and rich experiences in sustainable water use, and of the current administrative system is helpful in organizing the collection of large scale data, and there are already several case studies about the issue, then the risk could hopefully be relieved by the implementation of TSD measures.

(34) The integrative water security is shown in a hexagon in Fig 7.2-7.4, with the axis from the center to each vertex representing food, life, environment, ecosystem, economy and society

sub-security indicators respectively. We use the standardized index from -1 to 1 to represent its quantity, with –1 the worse and 1 the best. After consulting with various experts, we identified the exact position on each axis for each real state. Connecting all these points, we get a new hexagon, which represents the real state of the different sub-security. Then the area of the real hexagon is a measure of comprehensive water securities. The maximum security is 1, the security threshold is 0.25.

(35) The security index in 1997 from Fig.3 is 0.4798, above the security threshold 0.25. The security index in 2010 from Fig.4 is 0.2216 in BAU, below the security threshold 0.25, and 0.3954 in TSD respectively. The security index in 2025 from Fig. 5 is 0.3114 in BAU and 0.5561 in TSD respectively (See Fig.6). From Fig.3-5 you can see, in BAU, because of the fast economic growth, poor wastewater treatment ability and inappropriate water resource management, the ecosystem, environmental and life securities in 2010 and 2025 would be worst than those of 1997 and all are below the security threshold indicator. But in TSD, the situation is much better, where the security index in 2025 will exceed 0.4798, the one in 1997. Apparently, the life, ecological and environmental securities are much more serious than others and should be given much more attention. And if the measures suggested in TSD put into implementation, then almost all of the sub-securities are above the threshold except for the environmental security.

6. Water Strategies

(36) The measurement of water should not only be by its economic value, but also by its comprehensive Wealth, Health and Faith.

(37) Encourage ecological engineering for sustainable water cultivation: combining hardware, software and mindware.

(38) Beijing, for example, is currently facing a severe water shortage, and a water diverting plan from the Yangtze River is being planned. While, according to an investigation made by the local water saving agency, about 0.414 billion m^3 of current water use in Beijing could be saved, 0.257 billion m^3 of rain water and 1.0 billion m^3 of treated waste water could be recycled annually if

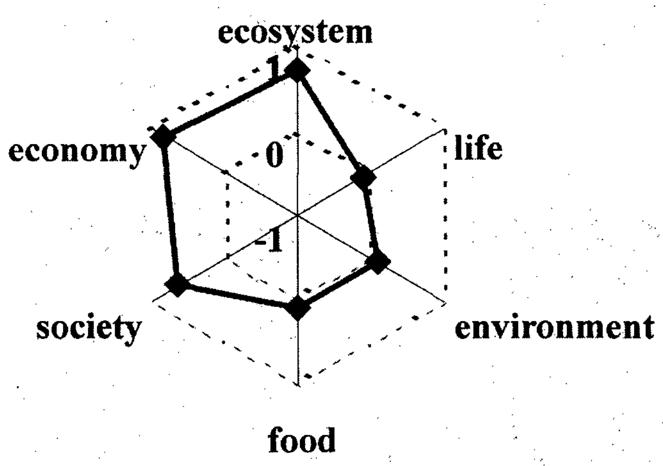

Fig.3 Water security in 1997

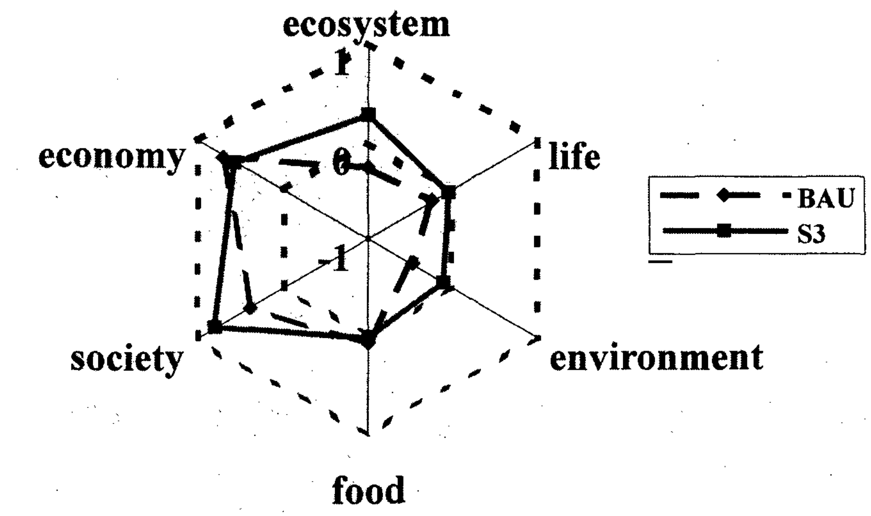

Fig.4 Water security in 2010

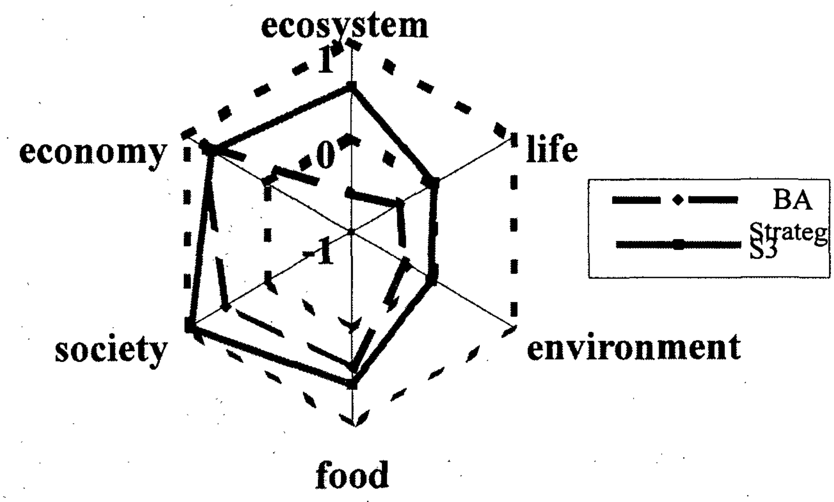

Fig.5 Water security in 2025

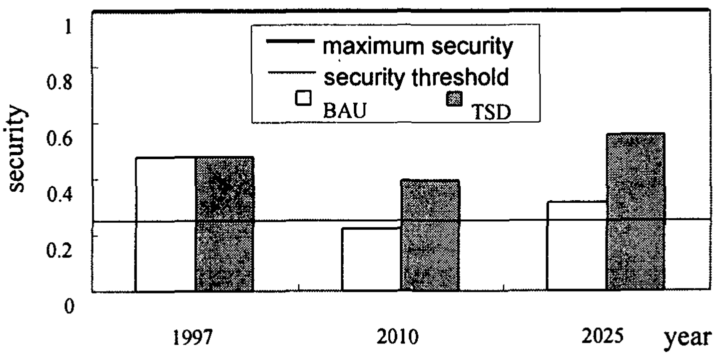

Fig.6 Water security from 1997 to 2025

appropriate measures are taken, helping to meet the 1.262 billion m^3 annual deficit of water needed for the future development of Beijing. This could help relieve the stress of diverting water from the Yangtze river basin on the local natural ecosystem and on local socio-economic development with a huge saving of money from the cost of engineering, the diversion of water from the Yangtze River.

(39) Agriculture is the key sector in water use, the priorities are

To adapt the temporal and spatial imbalance of water resource distribution, withstanding natural aridity and floods, constructing water conservancy works, and developing irrigation and drainage utilities.

To enhance the capacity building in water legislation, water pricing and water policy making

To reform institution for ecologically sound water management structures with an emphasis on inter-sectorial and inter-regional management.

To encourage water-saving technology, biological technology and ecological engineering.

To explore ecologically alternative water resources such as rain water, waste water and trans-basin's water diversion. For example, 33% of the Chinese population in 1992 lived in some 30% of the total land area, where the average precipitation between 1958 – 1988 was in the range of 400mm – 800 mm. This is just a semiarid and semi-humid area with a dense population badly in need of water. Collecting 1% of the rain water in 1% of this kind of land will provide about 180 billion m^2 of water annually.

To enhance eco-zoning and regional planning to optimize the agricultural water use through adjusting the pattern and structure of crops according to local ecological conditions and water carrying capacities.

To coordinate water conflicts between industrial, urban and agricultural use, between upper and lower reaches, and between generations, by introducing eco-mechanisms of incentive compensation, social cooperation and self-reliance.

To raise the awareness of decision makers, entrepreneurs and the public of water ecology and its effects on the economy.

To enhance regional and international cooperation in scientific research and technological transfer for water issues.

(40) Let every one have safe water and hygienic condition.

(41) Saving more water for nature is saving more water for ourselves and our offspring.

(42) Promoting regional cooperation, networking, ecologirization & globalization for water issues.

(43) The centralized policy-making mechanism has both disadvantage and advantage for destroying or restoring the water-ecosphere. Its disadvantage could be overwhelmed by combining appropriate scientific evaluation, public participation and social supervision.

(44) Emigration from the overloaded water-carrying capacity and ecologically fragile regions is necessary but needs careful human ecological planning and management.

(45) To divert water from south to north is necessary and beneficial to both man and nature in the North but needs sound and comprehensive ecological planning especially concerning the impacts on and compensation to the south.

(46) An ecologically sound watershed management structure should be enhanced by making consideration for integrating ecosystem conservation with local (especially upper reach area) economic development, and the strategy of compensation for their contribution to enhancing the nature service.

(47) To enhance the adaptability of human activity to the uneven water distribution and the high frequency of flooding and drought through ecological engineering.

7. Overall conclusion

(48) The word Crisis (Wei Ji) in Chinese has both the meaning of risk (Wei) and opportunity (Ji). Having a long tradition of sustainable water management and human ecological philosophy, in China the water vision, has both optimistic and pessimistic perspectives. Though the per capita water resource in China is only 35% and 75% of the world and Asia average level respectively, the spatial and temporal distribution is extremely uneven. Overloaded human activities are threatening regional food, health, life, economic, social and environmental security, but there are also big opportunities for alternative water resource exploitation and water saving. Through the above mentioned strategies, China can feed its 1.54 billion people with improved life quality and limited water resources by 2025 without significant grain imports from outside, though some(less than 10%) grain imports will benefit both China and the world. Here the key is technological innovation, institutional reform, lifestyle change, water diversion, ecological engineering and intelligent governance. Facing this challenge, China is standing on the crossroads towards either a miserable or a prosperous, future with the water-related fortune in its own hands.

REFERENCES

Ma Shijun, 1990. *A Perspective of Modern Ecology*, Science Press, Beijing.

Ma, S.J. and Wang R.S., 1984. "Social-Economic-Natural Complex Ecosystem". *Acta Ecologica Sinica* 4(1): 1-9.

She, Z.X., 1997. **The Water-Land Resources and the Regional development in Yangtze River Delta**. China's University of Science of Technology Press, Hefei.

Wang, R.S. and Ouyang, Z.Y., 1996. Ecological integration: the methodology of human sustainable development, *Chinese Science Bulletin*, vol.41, special issue, 47-67.

Wang, R.S., Zhao J.Z. and Ouyang Z.Y., 1996. **Wealth, Health and Faith, -- Sustainability Studies in China**, China's Science and Technology Press, Beijing.

Wang, R.S., Zhao, J.Z. and Ouyang, Z.Y., 1991. **Human Systems Ecology**. China Science and Technology Press, Beijing, 240pp.

Wang, R.S., Zhao, J.Z. and Dai, X.L., 1989. **Human Ecology in China**. China Science and Technology Press. Beijing, 251pp.

Rusong Wang, Hongzun Ren, Zhiyun Ouyang, Qingwen Min, Guobin Fu, Qiaoxian Zhang, Jingjie Yu, Xiaoke Wang, Xiwu He, Shaojun Yuan, Shiping Zhao, Han Xiao, 1999, Final Report of China Water Vision, Chinese Academy of Sciences (in printing).

Sustainable Utilization of Water Resource in China

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Water is a non-fungible resource for human existence and development. China is a country with frequent floods and drought disasters and shortage of water resource, and water issue is vital important for the country. Since the founding of the People's Republic of China, our government has made a great effort to improve water resources management by means of constructing water works on a large scale and has gained great achievements. However, water-related problems are still hindering the Chinese economic and social development. The sustainable utilization of water resource is the key problem for the economic and social development in China. It is my great pleasure to make a brief introduction to the sustainable utilization of water rescue in China at this symposium of "China Water" on the Second World Water Forum.

1. General situation of water resource in China

The total amount of water resource in China is 2800 billion m^3. The Rainfall season is basically synchronous with the hot season. The good natural environment creates favorable conditions for the existence and development of the Chinese nation. But the amount of water resource per capita in China is only 2300 m^3, which is 1/4 of that of the world. In addition, the uneven spatial and temporal distribution of the precipitation makes the country become one with frequent occurrence of flood and drought disasters.

Influenced by the natural conditions and the monsoon climate, the distribution of the precipitation in China is very uneven in a year and among years. About 70% of the total annual precipitation are mainly concentrated in the flood season, that is to say, about 2/3 of the total amount of water resource are from flood runoff, which always causes flood disasters during flood season. Especially, the regions in the middle and lower reaches of large rivers have more than one half of the country's total population, one-third of the total cultivated land and 70% of the gross national product. However, the most of the ground elevation in such regions is under the flood level of rivers, so that the potential flood disaster always threatens the economic development and the normal life of people.

The catchment area of water system to the north of the Yangtze River basin accounts for 63.5% of the country's territory, but its total amount of water resource is only 19% of the country's total. The area of the northwest of China accounts for 35.3% of the country's territory and its total amount of water resource is only 4.6% of the total. In three river basins of the Yellow, the Huaihe and the Haihe in the north of China, the amount of water resource per capita are 1/4 of that of the world. The drought and the water shortage have become main natural disasters in China, especially in the north part of China.

According to the historical records from 206 BC to 1949 AD, 1029 times of big floods and 1056 times of severe droughts occurred in China. Since 1949, the average area affected annually by floods and droughts is about 30 million ha, of which over 20 million ha is affected by droughts and 9.3 million ha by floods. The average area suffered a production loss more than 30% is about 13 million ha, of which over 8 million ha hit by droughts and 4.6 million ha by floods.

The existing area of soil erosion of low degree and above in China is 3.67 million km^2, accounting for about 38.2% of the country's territory, in which hydraulic erosion occupies 1.79 million km^2 and wind erosion 1.88 million km^2. Hydraulic erosion is the most principal type of soil erosion in China, mainly distributed in the vast areas south of the Great Wall and, in particular, is most serious in the middle reaches of the Yellow River and the upper reaches of the Yangtze River. Wind erosion (also called desertification internationally) is mainly distributed in the areas north of the Great Wall and areas along the lower Yellow. Lots of hill avalanche can be found in South China, and lots of landslide and mud rock flow can be found in the upper reaches of the Yangtze River and the upper reaches of the Pearl River in Southwest China.

2. Achievement of water resources development in China

Since the founding of the People's Republic of China 50 years ago, the water conservancy in China has gained a rapid development. Up to the year of 1998, the length of dykes in the whole country had been increased from 20 thousand km to 250 thousand km. The reservoirs in China had been increased from more than 20 to 84,000, with the total storage capacity of more than 460 billion cubic meters. These reservoirs have preliminarily controlled the ordinary flood and guaranteed the safety of more than 600 cities, 33 million ha of cultivated land and the main railway and transportation artery. More than 4.60 million water storage, diversion and pumping and water supply works have been constructed in the whole country. The annual water supply capacity of various facilities is up to 560 billion cubic meters. The exploitation and utilization rate of water resource is up to 20%. The irrigated farmland area has been developed from 16 million ha in 1949 to more than 53 million ha at present. Although the irrigated land is less than 2/5 of the country's total cultivated land, it yields 3/4 of the country's total food grain and 4/5 of the country's total cash crop. Development of farmland water conservancy has played a critical role to ensure successive bumper harvests and 500 million tons of grain production, making it possible to feed 22% of the world population with less than 10% of the world farmland. The total installed capacity of hydropower in the whole country has increased from 360 MW in 1949 to 64,000 MW at present. More than 300 countries (cities) mainly relying on hydropower have realized preliminary rural electrification and about 300 million people rely on small hydropower stations to supply electricity. The area of soil erosion of 740,000 km^2 has been preliminarily disposed. The total area of the terraced field, the valley flatland and the farmland formed by disposed sediment of 18.0 million ha has been completed. The diversified cash fruit trees and the forest for soil and water conservation of 40 million ha have been planted.

3. Key points of sustainable development of water resources in China

(1) Flood and water-logging

Heavy floods mainly take place on the plains of middle and lower reaches of major River and coastal plains. These plains are of fertile soil and dense population and with developed economy. Most of the elevations of these plains are lower than the flood stages in rivers. Levees are the principal measure to protect these plains. Once the flood level is higher than the standard of flood control, the economic loss brought about as large as 2/3 of the country.

The flood control system of large rivers in China is composed of dykes, reservoirs, Flood-storage and detention basins. At present, the major problem is that the flood control standards for large rivers are not high enough. It could only fight against a flood 1 in 10-20 years. If combining with a use of flood-storage and detention basins, it can only fight against a flood 1 in 20-50 years. For those medium and small rivers, their dykes only could fight against a flood 1 in 5-10 years. With increasing of population, rapid economic development and aggravation of river channels and lakes, the problems of flood control will be more and more serious.

(2) Shortage of water resources

Droughts may happen anywhere in China. The most serious droughts occur in North China, Western part of the Northeast China, Loess Plateau and Northwest China. Droughts may occur in every season in a year. As the area affected by droughts is quite large and the duration of drought is long, the effect of droughts on agriculture is very serious.

The agriculture in China is of irrigation type. At present, the area of drought-hit farmland in the whole country is up to 26.6 million ha annually. Among the irrigated farmland of more than 53.0 million ha in China, the annual water shortage volume is about 30.0 billion cubic meters. There are 76.0 million ha of cultivated land without irrigation facilities. Among 670 cities in the whole country, there are more than 400 cities with a problem of water abortage to different extent. By the middle period of next century, the population in China would be up to 1.6 billion and the irrigation area would be developed to 63.33 million ha. In addition, the urbanization rate of population in China would be increased from 28.7% at present to about 56% and the Chinese economy would reach a level as the medium-developed countries in the world. The supply of water will become the key constrain factor for economic development in the whole country.

(3) Water pollution

At present, the total discharge of the industrial and urban wastewater all over the country is 58.4 billion tons, and among them, only 23% have been concentratedly treated to reach the stipulated discharge standard, the reuse rate of treated wastewater is even lower. In one half of the country's total monitored river length, the water quality there cannot meet the requirements of drinking water standard. More than 90% of water body in cities all over the country are polluted to different extent. With increasing of population and development of economy, cities and towns, the pollution of water body will be more and more serious.

(4) Worsening of water ecosystems

At present, the area of water and soil erosion in China is 3.67 million square kilometers, accounting for 38% of the country's total territory, which makes the aggravation in rivers, lakes and reservoirs increasingly serious. The dry up of the rivers in the north region of China is more and more serious. The Yellow River dried up annually in 1990s with the average period of dry up of 107 days every year. In addition, there still exist the problems of lake shrink, deforestation, grassland degradation, land desertification, wetland dry, secondary salinization in irrigated area, and groundwater overdraft in some regions. All these problems cause the worsening of environment and the unbalance of ecology conditions in some regions.

4. Countermeasures for solving problems of the water resources in China

The Chinese government has treated the control of population growth, conservation of natural resources and sustaining of sound eco-environment as a basic national policy. The Government has paid a great attention to the issue of sustainable utilization of water resource. In view of the coordinated arrangement of population, resources, environment and economic development as well as the principles of "Overall planing, full-angle consideration, all-round treatment, integrated development ", the Government carried out the policies of water conservancy construction of "the combination of benefit generation with disaster abolishment, the equal stress on saving water and opening up new water source, and the simultaneously adoption of flood control and drought prevention". The construction of water conservancy and ecosystem has been developed in the whole country.

(1) Integrated regulation of rivers and lakes

The policies of "Combining flood storage and releasing, and taking flood releasing first" in large rivers and lakes should be carried out in a bid to improve the criteria of flood control and establish flood management system in ten years, which can defend the worst flood compared with that in the past half century. It is planned to set up a flood control system of combining structural and non-structural measures for the Yangtze River in order to fight against the maximum flood, which occurred in the 20th century. The structural measures consist of taking dykes as its base, the Three Gorges Project as its backbone, and other measures of reservoirs in main streams and tributaries, flood storage and detention basins, river training, polder embankment removal for releasing flood, returning farmland at lake beach to lake, soil and water conservation and afforestation. In addition, new plans of river harnessing will be implemented for the Yellow River, Songhua River, Nenjiang River, Huai River and other large rivers and lakes.

(2) Strengthening ecosystems building

The Chinese government has formulated a master plan for ecosystem building: by the year of 2010, to primarily achieve the objectives of harnessing and rehabilitation of the key water and soil erosion and desertification areas in the mid- and upper-reaches of the Yellow River and the Yangtze River; by the year of 2030, to take great efforts to improve the ecosystem in the country; by 2050, to basically establish a sound ecosystem appropriate to sustainable development. The principle of afforestation on hills and returning cultivated land to forest should be carried out. Lumbering of natural forests in the upper and middle reaches of Yangtze River and Yellow River shall be forbidden. Afforestation projects will be carried out in order to increase the forest cover percentage in such regions. The area of grassland and vegetation should be enlarged and restored. The comprehensive treatment of small watersheds should be exercised and the project of transforming hillside field into terrace land should be carried out in order to control soil and water erosion.

(3) The protection, exploitation, and rational utilization of water resources

The development and utilization of water resources should be insisted on the policy of simultaneous adoption of opening up new water sources, saving water and protecting water resources with the water-saving as the first priority and the principle of adapting economic and social development to water resources conditions. At present, the efficient utilization coefficient of agricultural irrigation water in China is only 0.4. The water saving irrigation technology should be greatly popularized. Water saving should be taken as core for the rehabilitation of all irrigation districts. With 30 year's efforts, the efficient utilization coefficient of agricultural irrigation water in China should be upgraded to over 0.6 and 10 million ha. Of irrigated area be increased. All these will provide China with the favorable conditions to realize the basic self-sufficient in food grain by 2030 to feed a population of 1.6 billion.

The industrial and domestic water users will mainly be the new users, which will greatly increase water consumption in future. They should be in accordance with the requirements of saving water and reducing pollution as well as the principles of "developers have to protect, users have to compensate, polluters have to be responsible, and damages have to restore". The Chinese Government has paid a close attention to the treatment of water pollution. The treatment of "three rivers and three lakes" (namely, the Huai River, Hai River, Liao River, Tai Lake, Cao Lake and Dianchi Lake) has gained a preliminary success. The construction of municipal sewage plants has been speeded up in several regions of China. The protection and management of water sources should be strengthened. The water quality monitoring and water pollution control in river basins should be enhanced. The reuse rate of the treated wastewater should be improved and the wastewater made as a resource.

To solve the water shortage in North China and the dry up of the Yellow River should be based on energetically carrying out water saving and making full and rational use of local water resource, and the overall consideration taken on the rational development of water resource of four large river basins (the Yangtze River, Huai River, Yellow River and Hai River). Meanwhile, the south-to-north water transfer project should be constructed in a proper time.

In the 21st century, the conditions of water resource should be fully considered in the course of economic and social development and the space planning of industry and agriculture in China. In the regions with the shortage of water, it is necessary to limit the crops and industrial projects, which need large water consumption. In the coastal areas, utilization of seawater should be fully taken into account.

(4) Implementing a system of the governmental CEO at all levels being responsible, increasing the investment of water conservancy construction

The Chinese government emphasizes the implementation of basic national policy and will carry out a system of the government chief leaders being responsible for the tasks. They have to adhere to their tasks and seriously fulfill all the assignments. The annual evaluation will be exercised during their assignment period. They have to report their work during the assignment before leaving the office and anybody who fails in the job will be investigated for the responsibility. In recent years, the Chinese government has greatly increased the construction investment of water conservancy and ecosystems. The central financial allocation of about 4.0 billion US dollars for water conservancy construction in 1998 and 1999 financial year had been made and the local governments at different levels had also increased the input for water conservancy construction. With the increase of water conservancy construction tasks, it is necessary to set up and perfect the input system of water conservancy adapting the socialist market economy and a mechanism that the state supports farmers to conduct farmland water conservancy construction.

(5) Strengthening the management of water resource

The Chinese government has paid close attention to manage the country according to the legislation and legislative construction. The following laws and regulations have been formulated and come into effect: "Water Law of the People's Republic of China", "Soil and Water Conservation Law of the People's Republic of China", "Flood Control Law of the People's republic of China", and "Water Pollution Control Law of the People's Republic of China". In addition, it is planned to draw up "Water Saving Law of the People's Republic of China", "Watershed Management Law of China", and "Management Regulations of Flood Storage and Detention Basins in China". It is to strengthen the unified management of water resource and adopt the management method of taking the river basin as a unit. The system of water permitting license should be carried out to promote completely the water demand management. It should also strengthen and perfect the enforcement supervisory system of water administration and strengthen the enforcement supervision work of water resource management. Development and utilization of water resources should be based on principle of market economy.

(6) Applying the advancement of science and technology and strengthening the international cooperation

For the river harnessing and water conservancy construction, it is necessary to widely apply new technologies and equipment. The key problems should be verified in a scientific way. We are willing to widely develop the international exchange and cooperation in the areas of the river training, management of flood storage and detention basins, water-saving irrigation and irrigation district rehabilitation, wastewater treatment and reuse, sea water utilization, the financing and water economy, and sustainable utilization of water resource, etc.

Water resources issue is a global hot topic in the 21st century and also the common concern among all the governments of all countries in the world. Now the Chinese Ministry of Water Resources treats the WATER as vital resources and we should utilize WATER not only by constructing a series of engineering projects, but also in a comprehensive way where water is related to the social, economic and ecological aspects. In the great undertaking of developing and exploiting the Western China, water resources will play a vital important role. I believe that this symposium on water resources in China will play an important role in promoting the cooperation and finding new friends and partners in the water resources development in the global scope. I extend my cordial congratulations to the smooth opening of this symposium and wish it a complete success.

Strategic Options for the China's Water Sector[1]

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1. Scenarios for the Future

From a water perspective, the People's Republic of China (PRC) of the year 2030 may be very different than it is today. If one were to simply project current trends, the outlook may not be positive. Flood damages, polluted rivers and lakes, regional and localized water shortages, soil degradation, and sedimented rivers and estuaries would continue to mount, with disastrous implications for the social and economic fabric of the nation. But *trend is not destiny*. Current trends can be arrested, and current problems can be turned into opportunities.

By the year 2030, one could equally envisage a second, more optimistic scenario: where Chinese society is living in harmony with its aquatic environment; where the water sector has built on its current engineering strengths to create a strong inter-disciplinary capacity and sound provincial and basin planning; where escalating flood damages have been reversed through a judicious balance of flood control and floodplain management; where water demands and availability are in dynamic equilibrium through balanced supply and demand management; where environmental degradation has been arrested by dealing with the root causes of pollution; where upper watershed issues and downstream adaptation are dealt with inter-dependently and effectively; where government policy, planning and scientific capacities are greatly strengthened, and most water services have become financially self-sufficient; where public awareness of the issues is greatly enhanced, and the general public contributes actively to devising solutions; and where there is clarity of purpose and technical strength at all government levels and in non-government sectors.

The government of the PRC is fully conscious of the dangers of the first scenario, and the importance of moving in the direction of the second. Indeed, if current policies and legislation were to be implemented with vigor, much could be achieved in this regard. This should be done as a first priority. But this may not be enough. It is our view that *Strategic Planning* could play an important role in moving the PRC further in the direction of the second scenario. That is the subject of this report.

2. The Role of Strategic Planning

Governments throughout the world are realizing that they must go beyond the symptoms of their water-related problems to their root causes. New mechanisms are required that protect the resource and allocate diminishing supplies among increasing and competing uses, and which treat

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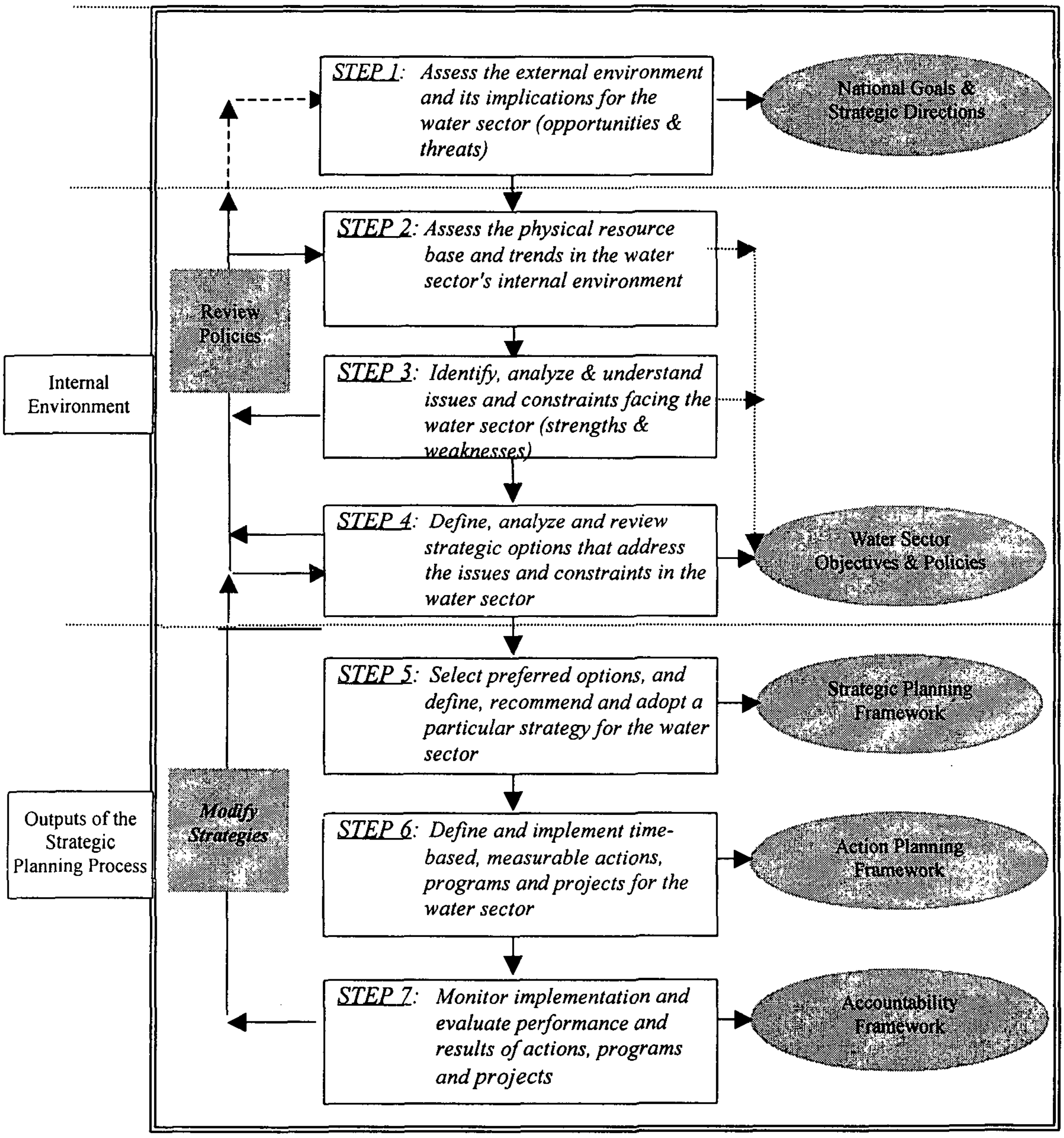
the quality and quantity of surface and ground water in ways that acknowledge their real value in social, economic and environmental terms. This is the very essence of sustainable development. These new approaches must clearly be more proactive anticipatory and preventive than in the past. In other words, they need to employ systematic foresight and strategic thinking. Some governments have progressed in this direction and much valuable experience has been gained. But each country faces different conditions. The PRC is a large and complex country and must devise its own solutions to its water resources problems.

Figure S-1: Seven-Step Strategic Planning Process



The following figure sets out the seven step strategic planning process that is presented in this report. It comprises three main stages: (i) an analysis of the context surrounding the water sector (the external environment) (Step 1); (ii) the analysis of the water sector itself (the internal environment) (Steps 2, 3 and 4); and (iii) representative outputs that simulate what the government might conclude if it was to adopt such a process in full (Steps 5, 6 and 7). These outputs have been made as realistic as possible based on discussions with the Technical Advisory Panel (TAP) appointed by the Ministry of Water Resources to advise the study team. The TAP has served as a *"proxy"* for inputs at the provincial, local and river basin levels, and as a sounding board to test the practicality of international experience in the PRC context. The simulated outputs also provide the basis for the study team's own recommendations.

Strategic planning has at its core *"foresight"*: that is how a sector's external and internal environments can be expected to evolve:

(1) The analysis of a sector's *external environment* seeks to understand how long-term national trends and issues -- political, demographic, economic, social, environmental and technological -- are likely to impact on the sector. Such an analysis typically must look 30 to 50 years ahead.

(2) The analysis of a sector's *internal environment* seeks to establish its capacity for responding to these trends in the external environment. It thus must be grounded in an assessment of the sector's current strengths and weaknesses, and how these can be exploited or addressed to meet future challenges.

The analyses of the external and internal environments allow sector managers: to set attainable goals and expected results for the sector; select strategies and action programs to achieve these goals and results; and assign accountabilities for performance.

3. Analysis of the External Environment

The review of the external environment (Step 1) focused on two profound transitions in the PRC: those from a command economy to a market based economy, and from a rural agricultural society to an urban-industrial society. These transitions were reviewed in the context of the demographic and other forces that are driving change; regional development trends and how they impact on the pattern of water use and abuse; and basic government structures, laws, goals and guiding policies that must frame any interventions in the water sector. This led to six key cross-cutting *strategic policy directions* to guide the evolution of strategies in the water sector. The agreed policy directions were as follows:

(1) Revise policy and legal implementing instruments to make them more comprehensive and effective;

(2) Clarify functions at each level while strengthening top-down guidance and bottom-up initiative;

(3) Promote integrated management to meet socio-economic priorities and realize sustainable development;

(4) Devise multi-channel financing and gradually adjust central expenditures;

(5) Strengthen incentives for efficient public services and market-like responses; and;

(6) Modernize water management through science, technology and good utility practice.

It should be noted that these policy directions would be similar for any sector, though they would need to be formulated in ways that addressed the specific characteristics of the sector concerned.

4. Analysis of the Internal Environment

Basic characteristics of the water sector were then assessed, along with an overview of institutional arrangements, policies, plans and future prospects (Step 2). This set the scene for identifying priority issues facing the sector (Step 3), and for evaluating options for addressing constraints in the context of relevant international experience (Step 4). International experience is itself reviewed at greater length in Annex A.

The analysis of the internal environment pointed to numerous issues, some of which require no new action, some of which can be handled through routine programming, and some of which require a more substantive response. In selecting those that required a more substantive response, the study team was guided by members of the Technical Advisory Panel. They highlighted the following:

(1) Due to its inherent importance, but also reflecting the 1998 floods and construction of the Three Gorges Dam on the Yangtze, the *flooding issue* is foremost in the minds of many officials. Major decisions have been taken in the light of the 1998 experience to contain damages during future floods ,but how to prepare for and manage floods remains an issue of the first rank.

(2) A second important issue, signaled by the 1997 drought and dramatized by the drying up of the Yellow River, is the question of *water scarcity,* especially in North China, and the associated issue of the perceived *inefficiency of water use*. The study of demand and supply suggests that, if the South-North Transfer project is built to transfer water from the Yangtze basin to North China, and sound policies and strategies are in place, then deficits can be contained. But the timing of the South-North transfer is uncertain; severe localized problems will occur in the interim; and achieving an acceptable balance between supply and demand will remain a formidable challenge.

(3) Water pollution is an obvious and growing issue. It was highlighted by the 1996 pollution crisis in the Huai River basin, and is receiving widespread media and political attention. The PRC is not alone in facing growing environmental pressures but the speed and scale of development in the PRC and its impact on the environment is perhaps unprecedented.

(4) Finally, *soil and water conservation* is an issue that is receiving great attention. No doubt much erosion is due to quite natural causes, but human induced impacts have accelerated sedimentation of rivers, reservoirs, lakes and estuaries. Moreover, the encroachment on wetlands has adversely affected their environmental values, besides reducing their natural capacity to regulate river flows.

Deficiencies were also identified in the institutional and financial means to address these core water resources problems. These deficiencies are as much concerned with implementation as with current policy or legislation. For instance, the unified administration and integrated management of water and related land resources are called for in the water law, and in other related laws and policies, yet this remains an elusive objective. Moreover, while the water law promotes comprehensive and specialty planning, practice falls well short of the ideal. In that regard, weaknesses were noted in data collection and analysis, planning and plan methodologies, consultation processes and adherence to plan requirements. Finally, it was concluded that financing of infrastructural development and recurrent O&M represents perhaps the most serious challenge facing the sector. The 1997 Industry Policy for the Water Sector addressed financing issues and promoted cost recovery, but implementation raises difficult issues if the funds required for essential resource administration and service delivery are to be assured

The strategy proposed therefore identified seven *Priority Issues*, formulated in such a way as to focus on central concerns in the PRC. Three issues relate to mobilizing the institutional and financial means for addressing water problems, and four relate directly to major water resources problems themselves:

Mobilizing the Institutional and Financial Means:

Lack of unified water administration and management

The gap between policy/planning and implementation

The inadequacy of financial resources

Addressing major water resources problems:

Escalating flood damages

Water scarcity and inefficient water use

Increasing water pollution

Soil erosion and ecosystem degradation

Options for addressing these issues were identified in the context of the six cross-cutting *strategic policy directions* set out above, and in the light of relevant international experience. Options in relation to the four water resources issues were reviewed in a broadly consistent way. They ranged from structural solutions, to more preventative and anticipatory non-structural approaches. For example, the flood issue can be addressed with storage and dike projects, by management approaches such as flood retention basins and flood proofing, or by more comprehensive floodplain management. Again water shortages can be tackled by new supply projects, by reallocation and improved operations, or by pricing and demand management. These approaches are not of course mutually exclusive and optimal solutions will invariably entail some combination of structural and non-structural approaches. Nevertheless, the limits to structural interventions have been reached or even exceeded in some cases, and the trend worldwide is increasingly towards reliance on non-structural solutions. In a sense, the real challenge of this TA project was to determine the extent to which that trend may or may not be applicable in the PRC.

In describing options for mobilizing the institutional and financial means, the same pattern is not directly applicable. Nevertheless, countries in general move over time from a sectoral focus in addressing institutional and financial issues towards a more integrated, comprehensive but decentralized approach. This is in line with general strategies for effective water management as for instance proposed by the ADB, and provides a coherent approach to reviewing the range of feasible options open to the PRC.

5. Representative Outputs of the Strategic Planning Process

The evaluation of options leads naturally to the concluding steps in the strategic planning process: that is the formulation of a preferred strategy (Step 5); the identification of actions to implement the preferred strategy (Step 6); and the preparation of a monitoring and evaluation plan to provide feedback on implementation, and support strategy revision and reiteration of the planning process (Step 7). Three frameworks were partially developed to illustrate the outputs of these remaining steps:

(1) A representative *Strategic Planning Framework* for analyzing the key issues in a manner that includes screening options and recommending a particular set of strategies;

(2) A representative *Action Planning Framework* for translating strategies into specific programs and projects (activities), identifying those who will implement them and over what period of time; and

(3) A representative *Accountability Framework* for assessing performance against stated goals and desired results or outcomes.

The three representative frameworks demonstrate conceptually how such frameworks should be prepared. Despite the abbreviated process, however, every attempt has been made to make them as realistic as possible, in particular through discussions with the Technical Advisory Panel.

The *Strategic Planning Framework* is a straightforward matrix of the seven priority issues and six strategic directions. Each issue was reviewed in the light of each strategic direction so as to develop a parallel set of strategies that address the issue concerned. The implications of all six directions were reviewed for consistency and completeness across each issue and, similarly, each direction was reviewed for consistency and completeness across the seven issues. Clearly, when the strategy elements in the framework are compared with the 9th Five-Year Plan and Objectives to the Year 2010, there is a stark difference. The plan represents largely traditional approaches, with an emphasis on government-funded capital works. The strategy elements, on the other hand, look far into the future, beginning to envisage a time when the government's role in financing services is much reduced but its capabilities in policy, planning, management, and science are much enhanced. That does not mean traditional approaches should be abandoned. Rather, the study team recognizes that the capital works scheduled in the five-year plan will -- and should -- go ahead but that they must be complemented by a broader range of alternatives. In practical terms, what is needed is some form of meshing of traditional PRC custom and emerging best practice on an international scale.

For this reason, the study team went beyond the 9th Five-Year Plan and Objectives to 2010 by identifying key *"initiatives"* under an *Action Planning Framework* designed to upgrade planning and management capacity over the longer term. To identify a manageable number of initiatives, the study team looked, in an integrative way, down the various issues addressed in the strategic planning framework, as well as across the various strategic directions. Figure S-2 summarizes the main thrusts that arose in the context of this analysis, and lists twelve initiatives thought to have

Figure S-2: Twelve Proposed Initiatives

Issue	Key Thrust(s) Arising out of the Strategic Planning Framework	Twelve Initiatives with Maximum Leverage for Meeting Key Thrusts
1. Lack of unified water administration and management	a) Integration across hydrological and administrative boundaries b) Unambiguous assignment of stewardship functions to provinces c) Improved RBC governance and assignment of functions to RBCs to complement the provincial role	(1) Preparation of National Water Framework Plan (NWFP) (2) Pilot provincial institutional review(s) and water resources plan(s) (3) Pilot river basin institutional review(s) and water resources plans
2. The gap between policy/planning and implementation	a) Upgrading and standardization of data programs at all levels b) Upgrading water resources planning skills and capacities	(4) National data collection & standardization program (5) Capacity building for water resources planning
3. The inadequacy of financial resources	Determining organizational and incentive structures that promote cost-efficient service delivery	(6) WSE reform and policy guidelines to promote autonomy and service efficiency
4. Escalating flood damage	Broadening the range of tools for dealing with floods and floodplain management	(7) Flood-related policies that promote balanced structural and non-structural solutions
5. Water scarcity and inefficient water use	a) Increased emphasis on demand management and water savings b) Using leverage of major projects to promote institutional reforms	(8) Programs that promote real water savings and effective demand management (9) Leverage of the South-North Transfer project to promote major institutional objectives
6. Increasing water pollution	Move from react and cure, to anticipate and prevent in addressing water pollution	(10) A coordinated pollution prevention strategy based on pilot interventions and guidelines
7. Soil erosion and ecosystem degradation	Dealing better with upstream and downstream inter-relationships	(11) Addressing upstream-down stream linkages at river basin level through integrated science.
1-7. Integration across all issues	Ensuring all water legislation and regulations are complementary and consistent	(12) *Option 1-5:* Revised laws and regulations to resolve problems of over-lap, weakness and conflicts in law

maximum leverage for furthering these thrusts. It must be reiterated that these are not the only initiatives that could have been selected, nor are they the only options discussed. In all cases, the proposed initiatives are comprehensive and integrative in line with international trends. In a sense, therefore, they incorporate many of the more specific options reviewed elsewhere in the report. In the Action Planning Framework, each of the twelve initiatives was analyzed with respect to six planning elements: strategic opportunities, key activities and results, legal implications, lead role, time frame and budgetary implications. If implemented, it is felt that the resulting action program would contribute over time to furthering a new balance in the water sector, and that this could contribute to the over-arching goal of sustainable development The final step in the process was to set out the expected results or outcomes in a form that can be used to measure progress and accomplishments during implementation. That is done in the *Accountability Framework*. For each issue, there is an overall goal, and one or more proposals (developed in the Action Planning Framework) which contribute to the meeting of that goal. For each proposal, an anticipated *"result"* is defined along with several *"deliverables"*, each of which has a clearly defined target completion date. Monitoring, evaluating and reporting against expected results or outcomes is critical to making planning and implementation dynamic rather than static. By continually monitoring progress against expectations, one can continuously learn and adaptively improve. Adaptive learning is the key to sustained success in any enterprise, and if conducted well the strategic planning process can help make that happen. The process demonstrated in a preliminary way in this report would hopefully make a contribution to learning and constructive change in the water sector in the PRC.

6. Conclusions and recommendations

The main conclusion of the report is that present approaches in the water sector need to be strengthened; and that the adoption of a systematic strategic planning approach could contribute importantly to meeting this objective. Nevertheless, it is important to recognize that the PRC already has relatively sound laws and institutions. There is a common tendency to conclude that the solution to any major problem is a change in the legal and institutional framework, which is deemed to have failed. Strategic planning promotes long term institutional change, looking far ahead in the hope that today's decisions can be improved by anticipating what is to come. But change may take years to put into effect, and one thing is certain: floods, droughts, and a rising population will not await an ideal institutional or legal system. The benefits of strategic planning are therefore no excuse for avoiding action now.

The study team has therefore prepared recommendations that could be implemented without major study as well as those with a longer-term purpose that correspond to the twelve initiatives identified in the Action Planning Framework. The recommendations fall into four broad categories: (i) those that can receive immediate consideration; (ii) those that address critical issues of inter-basin transfers, inter-provincial allocations, and coordination across provincial and basin boundaries; (iii) those that could be implemented primarily on the initiative of MWR; and (iv) those that require action by ministries and agencies in cooperation with MWR. Recommendations are coded according to whether they address institutional issues at a national (N), provincial (P) or basin (B) level; or whether they address major water resources problems (WP). All need further review to accommodate the views and interests of the agencies concerned and, while general priorities are proposed, all could proceed simultaneously. In practice, if accepted, implementation will undoubtedly over-lap and be undertaken in parallel.

(1) Actions that are recommended for immediate consideration

These require changes in policy and practice, some of which may be difficult and/or controversial, but they can be implemented without substantive further study or international assistance:

N-1 A National Water Resources Coordinating Committee should be created under the State Council to direct and supervise new initiatives in the water sector. The NWRCC should be assisted by a National Technical Advisory Committee. A secretariat should be established in MWR.

N-2 In association with other national ministries, agencies and stakeholders at every level, MWR should reiterate the strategic planning process (SPP) for the water sector. This should be coordinated with any follow-up to this TA study, and with the preparation of a Water Vision for China to be presented at the World Water Vision conference in March 2000.

N-3: MWR and NDPC should establish a joint task force to prepare a proposal for a centrally funded program that would provide budgetary incentives and support for selected institutional reforms in the water sector at provincial and basin levels.

P-1: Each province should establish a Provincial Water Resources Coordinating Committee to direct and supervise major new initiatives in the water sector, advised by a Provincial Technical Advisory Committee and with the DWR providing the secretariat.

P-2: Each province should implement a SPP for the water sector. The SPP should follow the approach at national level while being adapted to the needs of the particular province concerned

P-3: Provinces should be assigned primary responsibility for stewardship functions for the water within their boundaries. They should fund stewardship functions from the consolidated budget to which all income from such functions (resource fees etc.) should return. Staff should be precluded from selling data or utilising government assets or their technical skills for commercial purposes.

P-4: Provinces should streamline regulatory organizations both for resource (quantity and quality) and economic (enterprise) regulation, and make such changes as thought appropriate to strengthen transparency, accountability and performance

P-5 Provinces should review options for strengthening real-time management of multi-purpose and water wholesaling facilities, in particular so as to consolidate management of such facilities under independent entities at a sub-basin, basin or provincial level; and for formalizing relationships between bulk water supply and service delivery entities, e.g. through contractual arrangements.

P-6: Provinces should review options for improving the performance of service delivery entities, paying particular attention to: providing service entities with managerial and financial autonomy; clarifying ownership and risk, in the first instance by promoting public utilities and user-owned organizations; and integrating service delivery within defined areas. The potential for public-private partnerships should be explored wherever appropriate.

B-1: MWR in cooperation with the Ministry of Justice and other agencies should draft proposals for providing RBCs with an independent corporate status. Provision should be made for split-basin arrangements for the Yangtze and Yellow River basins, and for mechanisms that address aquifers shared between provinces and/or RBCs. The option of individual laws for specific basins should be assessed, along with a phased implementation of the reforms starting with high priority basins.

B-2: Each RBC should implement a SPP for the basin concerned. The SPP should follow an approach comparable to that in this study, but adapted to the needs of the basin concerned.

B-3: The RBCs should review how they complement provincial institutional structures. As and when formal allocation and other agreements are reached on the shared waters of inter-provincial basins, these should be incorporated within real-time operating and drought management plans.

(2) Actions that address inter-basin transfers, inter-provincial allocations & provincial/basin overlaps

Water allocation and inter-basin transfers will remain highly controversial, and solutions can only be reached at the highest level of government. However, their importance is such that they must receive priority. The primary mechanism proposed is the National Water Framework Plan, supported by a review of the potential leverage of the South-North Transfer project. The provincial and basin pilot programs would complement the NWFP and may need to be phased accordingly. In the interim, on-going provincial and basin projects could be adapted to respond to the proposals contained in this report. The NWFP and the provincial and basin pilot programs may benefit from international assistance.

N-4: *(Initiative 1)*. Subject to NWRCC approval, MWR should prepare detailed TOR for a National Water Framework Plan (NWFP) and create a unit to take the lead in its preparation. The involvement of the planning departments of other national ministries and agencies should be secured by inter-agency agreements supervised by the NWRCC.

P-7: *(Initiative 2)*. One or more provincial governments should undertake a comprehensive review of their institutional structures in water resources management, including preparation of a provincial water resources plan, to explore the implications of consolidating resource stewardship functions in the province. The results would be made available to other provinces through workshops, discussions and reports.

B-4: *(Initiative 3)*. One or more RBCs should undertake a comprehensive review of their institutional structures and functions for coordinated basin management, and prepare a revised basin water resources plan. They would recommend how RBC arrangements should complement those at national and provincial level. The results would be made available to other RBCs and more widely through workshops, discussions and reports.

WP-3: *(Initiative 9)*. The government should review preparation studies for the South-North Transfer project in the light of this report, and assess whether the leverage of project financing could help promote inter-provincial agreements and institutional reforms at provincial and basin levels.

(3) Actions that could be implemented primarily at the initiative of MWR

The proposed flood policy review responds to a critical current concern and should receive high priority. Comparable priority should be given to the review of water savings programs, given that preparation of existing programs is already far advanced. Selected international assistance might be needed in each case, primarily to ensure that programs fully incorporate the lessons of international experience:

N-5: *(Initiative 4)*. MWR should create a task force comprising major data collection agencies and data user organizations under the chairmanship of the Department of Hydrology (DH) to review and formulate an expanded national basic data program.

N-6: *(Initiative 5)*. MWR should undertake a coordinated program to strengthen capacities for water resources planning at central, provincial and river basin levels.

WP-1: *(Initiative7)*. MWR should undertake a comprehensive review of flood control and flood plain management with a view to evolving a new balance between structural and non-structural measures in addressing flood issues. The key result would be to recommend a new flood policy including a much broader and integrated array of options than has traditionally been the case.

WP-2: *(Initiative 8)*. The Water Savings Office in the MWR should review its on-going programs for promoting water savings from two main points of view: (i) how far they exploit the real potential for water savings not only at the local (micro-) level, but also at the sub-basin and basin (macro-) regimes; and (ii) how far they lead to the removal of barriers to adopting demand management measures at national, provincial, local and basin levels.

(4) Actions to be implemented at the initiative of ministries and agencies in addition to MWR

These will need further review by the concerned ministries and agencies to ensure that they are adapted to the needs and priorities of the agency concerned. In practice, therefore, they may receive lower priority. Once revised, consideration should be given to the need for international assistance in respect of each specific case:

N-7: *(Initiative 6)*. The MWR, Ministry of Construction, SEPA and other relevant ministries and agencies should form a task force to undertake a broad comparative study of the early performance of WSE reform efforts in the different provinces of the PRC, and to define the constraints to meeting the user and polluter pay principles in each major sub-sector.

N-8: *(Initiative 12)*. The MWR, Ministry of Justice and other agencies should establish a joint task force to undertake a comprehensive review of water and related legislation in close association with the committee already assigned to revise the water law.

WP-4: *(Initiative 10)*. SEPA and other concerned agencies should review the potential for accelerating introduction of pollution prevention techniques and technologies through pilot projects in one or more industrial groups, with a view in the long-term to preparing a pollution prevention strategy.

WP-5: *(Initiative 11)*. The Ministry of Science and Technology should establish an inter-disciplinary task force to evaluate inter-relationships between upstream actions and downstream impacts within a catchment framework, and propose how best to adjust to inevitable ecosystem changes.

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Sustainable Development and Water Resources Protection in the Yangtze River Basin

Lida Weng

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Abstract: This paper briefs the present situation of the Yangtze water resources protection and its importance to the sustainable development of China's social economy. The future planing for water pollution control in the basin has been described.

The Yangtze River is the largest river in China. With a length of 6,300 km, the Yangtze's drainage area covers 1.8 million km^2, amounting to 19% of China's total land area. Yielding a mean annual runoff of some 1,000 billion m^3, the Yangtze ranks the third in the world regarding both the length and the mean annual runoff. China is short of water resources, however, the Yangtze River basin, with over 1,100 mm rainfall pre year in most parts of the basin, is endowed with rich water resources, its annual runoff entering the sea occupies one third of the nation's total.

The Yangtze basin is one of the cradle where the Chinese nationality originated from. It is also known as a treasure house of the biota. The basin has a total lake area of 20,000 km^2 with more than 300 species of fish. The Chinese river dolphin, Chinese sturgeon, paddlefish and the Yangtze sturgeon, etc. are the rare and endangered species under nation's protection. In addition, the basin is abundant in terrestrial fauna and flora resources. The upper basin is China's second largest forest area, where famous rare and endangered plant species, such as *Metasequoia glyptostroboides*, and *Cathaya argyrophylla* can be found. A variety of wild animals specially protected by the nation, including mammals such as Golden monkey. Giant panda, Chinese river dolphin, birds as White stork, Chinese tragopan, reptiles as Yangtze alligator, also can be found.

Historically, the Yangtze basin is one of the important bases for industrial and agricultural production. One half of the gross grain yield, and 48% of the nation's gross output value of industry and agriculture come from this area. Along with the implementation of " Reform and Open Door" policy, especially the development of the Pudong new zone in Shanghai and the construction of the Three Gorges Project, the Yangtze basin has become one of the most vital and fastest growing regions in the nation.

Water is the most essential element for people's life, social development and industrial and agricultural production. It is not only one of the environmental components, but also one of the most important resources. However, water resources in China is in short situation and the mean quantity per capita only accounts one forth of the world's average. Besides, the uneven spatial and temporal distribution further intensify and worsening the situation. Due to the great importance of the Yangtze water resources for the nation, to ensure the sustainable development, coordinate the contradiction between the economical development and environmental protection has become one of the urgent tasks for the nation..

Changjiang Water Resources Commission (CWRC) is the Largest One of the 7 River Basin

Authorities dispatched by the Ministry of Water Resources in China. CWRC is responsible for integrated water resources management of the basin; development, utilization and protection of the Yangtze water resources. planning, surveying, design, scientific research of the Yangtze River and the major water projects in the basin. With staff number of 10,000, of which 6,700 are engineers and technicians, CWRC consists of following major parts:

(1) Planning & Design Institute

(2) Bureau of Hydrology

(3) Bureau of Surveying & Measurement

(4) Yangtze River Scientific Institute

(5) Yangtze Valley Water Resources Protection Bureau

(6) Bureau of Water & Soil Conservation

(7) Headquarter of Flood Control of the Yangtze

(8) Bureau of Water Policy & Water Resources, etc.

As one of the major parts of CWRC and subordinated to both the Ministry of Water Resources and State Environmental Protection Administration, Yangtze Valley Water Resources Protection Bureau (YVWRPB) was founded in 1976. With Research Institute for Protection of the Yangtze Water Resources (RIPYWR) and Yangtze Valley Water environment Monitoring Center(YVWEMC) as its technical support bodies, YVWRPB is responsible for protection and management of the Yangtze water resources and water environment in the process of development, utilization of the Yangtze water resources.

Environmental protection is a basic policy of China The Chinese Government has issued " China's Agenda 21- White Paper on China's Population , Environment and Development in the 21st Century". It is the guideline for effectively balancing the protection of environment and natural resources with sustainable economical growth. In addition, since 1970's, a great number of laws and regulations related to environmental protection have been formulated and issued by the National People's Congress, the State Council or Ministries concerned. Among them the Environmental Protection Law of P.R.China, the Water Pollution Control Law of P.R.China and the Water Law of P. R. China are the major ones related to the Yangtze water resources protection. All the principles specified in these laws must be strictly followed in all economical and production activities.

However, in the last 20 years, along with the fast economical development and population growth, China has been facing more and more serious environmental and ecological problems. Since 1970's, especially during the last two decades, along with the economical growth and population increase, water pollution in the Yangtze basin has been showing an deteriorating trend. The protection of the Yangtze water resources has attracted a wide concern in the nation since 1970's. A river basin management system has been formed and a basin-wide water quality monitoring system, consisting of 551 water quality stations and 680 WQ sampling cross-sections, has been established since then to periodically watch the changes in water quality of the River due to the industrial and domestic discharge. To tackle the increasing water pollution issues, The Forth National Environmental Protection Conference, held in 1996, listed the water pollution control as the most urgent task for the nation's environmental protection. Besides, it has been requested that all the cities with population of more than 500,000 should build wastewater treatment works to reduce the pollutant discharge. Meanwhile, 15 types of small scale of enterprises with heavy pollution discharge, including paper-mill, chemicals, sulfur and charcoal, etc., would be forced to close down or change the products. Three rivers, the Huaihe River, Haihe River and the Liaohe River, and three lakes have been selected as the nation's key water bodies to be tackled before the end of this century. The Yangtze is not on the list, yet all the three lakes, namely the Taihu Lake, a trans-boundary lake between Jiangsu and Zhejiang province, the Dianchi Lake in Yunnan province and the Chaohu Lake in Anhui province all are located in the Yangtze basin. The Yangtze River itself, although due to its huge runoff volume and self-purification capability, its water quality remains in relatively good condition so far as compared with other rivers in China, but has been showing a apparent deterioration trend in recent years. Especially in the city reaches of the mainstream of the Yangtze, a special study indicated that, the pollution belts have been formed along the river bank and the total length is increased from 460 km in 1982 to exceeds 560 km in 1992. A special survey carried out by the Yangtze Valley Water Resources Protection Bureau showed that the total wastewater amount discharged from the basin has reached more than 15 billion t in recent years, which amounts to almost 40% of nation's total. As the result, a number of the tributaries have been seriously polluted and eutrophication has become a common threat to the lakes. Due to lack of the treatment facilities and techniques, in some area including the Three Gorges region, the solid wastes and domestic rubbish have been piled up along the river sides, becoming a great threat to the water quality of the Yangtze.

The impact of the Three Gorges Project on environment and ecology has attracted wide attention in both China and abroad. According to the EIS for the Project jointly compiled by EIA department and the Research Institute for Protection of the Yangtze Water Resources (RIPYWR), the construction of TGP will produce enormous and huge benefits in flood control, power generation and navigation, etc., and its main negative impacts will be concentrated in the reservoir region, of which the potential deterioration of water quality due to the reservoir formation is the critical one. After impounding of the TGP reservoir, the flow velocity and turbulent diffusion capacity will be decreased, in addition, the resettlement of 1 million people in the reservoir region will also exert significant impacts on the water quality of the reservoir. Therefore, both engineering and non-engineering measures should be applied to protect the environment and ecology in the reservoir region.

Upon the countermeasures proposed in the environmental protection planning for TGP's reservoir region, the planning for water resources protection of the Yantze mainstream as well as the planning for water pollution control of the Taihu Lake, a large number of environmental infrastructures are to be constructed in the near future in the Yangtze basin. For example, with the financial assistance from the Danish government, the Chongqing city started the construction of the first wastewater treatment work, the Tangjiaqiao treatment works in 1994. According to the planning of the city's environmental protection, 7 treatment works are to be built and the total treatment capacity will reach 770,000t per day by the year of 2010. At the same time, a number of the treatment works will be constructed in many other cities and counties in the reservoir region with scale of 8,000t to 25,000 t of treating capacity per day to cut down the pollution loading entering the reservoir. In Wuhan, the largest city in central China, a wastewater treatment works is under construction with the financial support from the World Bank. It is estimated that, in order to fulfill the goal of controlling the water pollution in the Taihu Lake region, more than 30 wastewater treatment works are to be newly built or enlarged in the next few years with a total treating capacity of about 1.7 million t per day, which will totally cost more than 3.3 billion yuan RMB.

Table 1 Plan of Wastewater Treatment Works in Chongqing

Name of Works	Year of Completion	Treating Capacity(t/day)
Tangjiaoqiao	1997	60,000
Chunshidai	2001	150,000
Yangkungqiao	2000	160,000
yaba Cave	2003	150,000
Dahuachi	2004	150,000
Changshao	2005	100,000
Bibeihe	2010	-----------
Total		*770,000*

To ensure the sustainable development in the Yangtze basin and maintain the sustainable utilization of the Yangtze water resources, following measures need to be implemented in the near future:

(1) Set up a decision making system, which combine both the data base and the graphic base of water quality, quantity, hydrology, topography, vegetation, land use, transportation, pollution sources, industry and agriculture, etc.; water quality simulation models; GIS and RS information and tools and so on, to provide the river basin management of water resources protection with scientific basis.

(2) Upon the requirement of central government and pollution control planning, build wastewater treatment works in the major cities and counties in the basin. Special attention needs to be paid to the TGP reservoir region, advanced and practical technology and facilities for treating domestic sewage suitable to mountain region, economical and easy to be operated need to be introduced.

(3) Advanced but economical technology or facilities for solid waste disposal, treatment, reuse or recycling are also needed to be developed.

(4) Other special techniques for control of oil pollution and eutrophication, especially removal of nitrogen (TN) and phosphorus (TP) need to be developed or introduced.

(5) Monitoring techniques and facilities for water quality, aquatic biota and pollution source,

especially those suitable for field measurement with high automation, need to be developed or introduced.

(6) To better implement the program, technical training for personnel engaged in the management needs to be provided.

(7) To ensure the smooth implementation of all the planning mentioned above, necessary funds are needed, in which the international financial organizations can play an important role in helping China to protect the Yangtze water resources and promote the sustainable development in both the basin and the nation.

Due to the great importance of the Yangtze water resources in the sustainable development of China, to effectively control the water pollution, stop the deterioration trend of water quality to protect the Yangtze water resources has become a urgent task. The Chinese government has recognized the importance of protecting environment and ecology. It is anticipated that, in the next few decades, large number of treating facilities for wastewater and solid wastes will be built in the Yangtze basin, which will provide foreign investors, especially those international financial organizations huge market and good opportunity to help China to improve its environment. It, in turn, will also be a great contribution to global environment improvement.

Water Environmental Problems and Ecological Options in China

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In the 21st century, China water security will be challenged mainly from water shortage and water pollution. Water pollution in China has not only deteriorated scarcity water resource, but also has caused great economic loss and harm to human health. Based on overall analysis of water pollution and water environment, this paper is to seek an ecological solution for China water environment problems.

1. Pollutants discharge

The main sources of China's water pollution are industrial and municipal wastewater discharges, agricultural runoffs of chemical fertilizers, pesticides and animal manure and leaching of solid wastes. In 1997, total wastewater discharge was 41.6 billion tons, of which 18.9 billion tons was from municipal sources, and 22.7 billion tons was industrial wastewater including wastewater discharged from rural and township enterprise. In the case of industrial wastewater, industries at the county level and above discharged 18.8 billion tons, while town and village industry discharged 3.9 billion tons.

The total COD was 1.76×10^7t, industry was the main contributor of discharged COD, while rural and town enterprise discharged 4.1×10^6t of COD, about 38% of total COD from industry.

Over the past decade, even with the large increase in industrial growth total industrial wastewater discharge has not increased. However, the proportion of the discharge not meeting discharge standards has risen significantly largely due to the large increase of town and village industry.

(1) Industrial wastewater

Paper making industry, food and drink industry and chemistry industry were the main COD contributors in industry. They discharged 42%, 28%, and 9% of total COD respectively. Other industrial sections only discharged 21% of total COD. Petroleum chemical industry, metallurgy industry, and machinery industry discharged 29%, 21%, and 13% of total petroleum pollutants respectively. Chemistry industry was the largest discharger of mercury, arsenic and cyanide pollutants, about 42%, 46%, and 28% of total discharge of these pollutants respectively. In addition, petroleum and chemistry industry discharged some toxic and harmful pollutants, which are not listed in control-targets chemicals yet.

(2) Agriculture pollution

Agriculture is the main source of non-point pollution, resulting from chemical fertilizer and pesticide application. The amount of chemical fertilizer and pesticide use in agriculture was increased rapidly. In 1998, the total amount of chemical fertilizer and pesticides were used 4.1×10^7t and 1.3×10^6. They were doubled during last 10 years. The wastes from husbandry increased very quickly as well, especially in metropolis area, for instances, the BOD5 discharged from husbandry was 30×10^4t, which was three times of BOD5 from industry. Most of the chemical fertilizer and husbandry wastes drain into rivers and lakes.

(3) Urban sewage

In 1997, there were 668 cities and 194.44 million people living in the cities. The urban sewage was estimated about $3.51\times10^{10}m^3$ (including domestic sewage and industrial wastewater drained into urban drainage system), only 13.6% was treated, 86.4% urban sewage was discharged into rivers and lakes without adequate treatment.

(4) River and Lake Sediments

It has been tested that the most chemistry reactions occur on particle surface in water. These particles are not the pollutants, but also the carriers of other pollutants. Most particles with attached other pollutants become sediments of rivers or lakes. These sediments release pollutants gradually and become a main source for many lakes in China. The research suggested that the Tianchi lake in Kunming would remain eutrophication resulted from sediments for 50—100 years even without any pollutants discharged into the lake from now. It implies that sediments will trouble water environment in the new century for long time, even after all industry wastewater and urban sewage are treated before discharge.

The leaking oil and wastewater discharge from ships in rivers were also an increasing water pollution source. In Yangtze rivers, for instance, 5,000 t of oil, 9.0×10^7t of wastewater, and 8, 000 solid waste from 300,000 ships and other navigation vessels were discharged into the river without adequate treatment.

2. Water Environment Pollution

(1) River environment pollution

In China, the rivers were widely polluted. According to a national wide water quality survey in 90's. In total 5.3×10^4km surveyed rivers, fishes were extinct in 45% of surveyed rivers because of water pollution, water in 23.3% of surveyed rivers cannot be used for irrigation. It means that 68.3% of surveyed rivers were polluted very server. The main pollutants included organic matter, ammoniac nitrogen, petroleum chemicals, and heavy metals.

Table 1 summarizes recent data on water quality in the major rivers. The poor quality of rivers in north-eastern China reflects high rates of urbanization and industrialization in this region. For the Haihe, Yellow and Huaihe rivers, urbanization impacts are aggravated by low river flows and limited natural dilution capacity. In contrast, large discharges and the resulting high dilution capacity support a significantly better average quality of rivers in southern and inland China. Occasionally as in 1996 in the Huaihe basin, pollution levels reach unacceptable levels and emergency measures had to be taken to resolve a problem that threatened human health including closure of polluting industries resulting in lost employment and incomes.

Table 1 Surface water quality

	Proportion of River length %		
	Class I & II	Class III	Class IV & V & over
Songhua-Liao Rivers	2.9	24.3	72.8
Haihe-Luanhe Rivers	17.6	31.2	51.2
Huaihe Rivers	17.6	31.2	51.2
Yeellow Rivers	8.2	33.7	27.5
Yangtze Rivers	38.8	33.7	27.5
Pearl Rivers	49.5	31.2	19.3
SE. Rivers	40.7	318	27.5
Inland Rivers	63.5	25.4	11.1
Total China	32.2	21.3	46.5

Class I, II, & III: Direct human contact and use as raw water for potable supply.

Class IV: Restricted to industrial use and recreational use other than swimming.

Class V: Restricted to irrigation.

(2) Lake pollution and eutrophication

According to water quality investigation in 23 main lakes in China, the total nitrogen of all surveyed lakes were higher than 0.2mg/L, in one third of lakes it was higher than 5.0mg/L. The total phosphorus of 92% of lakes were higher than 0.02mg/L, in half of lakes it was over 0.2-1.0mg/L. The lake pollution is very server, for example, the Tianchi in Kunming and Chaohu Lake in Anhui, their water quality was worse than class V, even cannot used for irrigation. The similar situation was happened in Taihu Lake in Jiangsu.

(3) Marine water pollution

According to marine water environmental monitoring, water quality in 53.4% of offshore area was worse than class III of marine water quality standard in 1998, only 18.7% of offshore area can meet class I. The water quality in Eastern China Sea is worst. The concentration of all 12 monitoring items, including activated phosphate, inorganic nitrogen, lead、petroleum, mercury, BOD、COD, were higher than the lowest standard. Copper, mercury, cadmium, hexachlorocyclohexane, and dichloro-diphenyl-trichloroethane pollution mainly happened in sea area near Pearl River estuary.

Since water pollution, the red tidal frequency and area have been increased in past three decades, the red tidal in Bai Bay, for instance, was recorded 3 times before 60's, 9 times in

70's, 74 times in 80's, and 34 times in 1990, 22 times in 1998. The area and lasting time of red tidal were extended. The red tidal occurred in Bai Bay in July 1999 covered 4,600 km^2, and lasting for near one month.

Marine pollution mainly comes from terrestrial sources. It is estimated that annually about 1.02×10^{10} m^3 of wastewater drained into the sea, and COD 1.3×10^7t, petroleum 1.7×10^5t, inorganic nitrogen1.3×10^6t, inorganic phosphorus 1.4×10^5t, cyanide 1,467.4t, lead 3,590.6t, cadmium 512.5t, mercury 70.35t, arsenic 6,248.8t. In addition, the oil leaking and the ship accidents were also important pollution sources. It was reported that 506 oil-leaking accidents were happened every year on average.

(4) Ground water pollution

Groundwater is also big environmental problems in China. According to groundwater assessment for 69 cities in five northern provinces and autonomous regions (Xinjiang, Gansu, Qinghai, Ningxia and Inner Mongolia), no city had Class 1 groundwater, 10 had Class 2, 22 had Class 3, and 37 had Class 4 and 5. A water quality assessment of 2015 wells in the Haihe River Basin showed that two thirds of the investigated wells did not meet quality standards for drinking. An investigation of ground water quality showed that more than 90% ground water of cities in northern China has been contaminated, 20% of them cannot be used as drinking water source. A distinct water quality problem reflected in these results is the widespread natural occurrence of fluoride in groundwater. The health of many millions living in north China has been adversely affected, both in cities such as Tianjin and in the mid-Yellow river basin.

3. The Damage Result from Water Pollution

The damage caused by water pollution has been got widely attention (Table 2). Since 90% of waters in urban area were polluted, hundred millions of city's residents were under the threats of losing clean drinking water. According a national wide survey by Ministry of Agriculture, the polluted water irrigation also leaded to lost grain output estimated at millions of tons, and 10% of grain production cannot meet the national sanitation standard. In the heavy polluted region, the amount of some rudimental pollutants in agricultural products, 12% grain, 17.6% vegetable, 8.6% meat, 19% eggs and 2% milk, was higher than permitted amount of national environmental standards. The health of many millions has been adversely affected. The economic loss resulted from water pollution each year was widely believed about 0.8—1.5% of China's GDP, although some researchers suggested that the economic lose could be as high as 4.42% of China's GDP.

Table 2 Economic lose caused by water pollution, $x10^8$RMB

	Researchers			
Items	Guo	WB	Sun	Zhen
Health	83.17	41—67	236	165.1
Agriculture				
Yield reduction	2.4	26—34	14.8	47.4
Husbandry	1.2		12	
Fishery	2.6		4.6	48.8
Industry				
Lack of water	65	25—33	128	65
Wastewater treatment	2.3		69.2	
Total lost caused by water Pollution	251.83	97—140	477.6	586.4
Total lost caused by environment pollution	381.6	297—437	1096.5	1085.1
Percentage of lost of water pollution in (%)	66	32.3	43.6	52.4
GDP ratio of economic lost by environment pollution (%)	6.7	1.7—2.5	4.25	3.16
GDP ratio of economic lost by water pollution(%)	4.42	0.55—0.81	1.85	1.66

4. The Trends of Water Pollution

Based on the water consumption prediction in cities and industry, the urban wastewater was estimated $6.5x10^{10}m^3$ in 2010, $9.6x\ 10^{10}m^3$ in 2030 (Table 3). It was planned that the urban wastewater treated rate would be raised to 40% in 2010 from 11.34% in 1997.

Table 3 Urban wastewater prediction

	Wastewater($x10^8m^3$)		
Source	1997	2010	2030
Domestic sewage	175	329	461
Industry wastewater	176	321	499
Urban wastewater	351	650	960

There are four possible water pollution trends in China in future 30 years.

(1) The water pollution expands rapidly; water quality deteriorates with economic growth, as the situation right now.

(2) The water pollution continues expanding, water quality deteriorates with economic growth, but the expanding degree and extent is slower than economic growth.

(3) The water pollution can be controlled, and realize a "zero" growth of wastewater

discharge. The water environment will be improved in some extent.

(4) The water pollution can be controlled effectively, and realize a "negative" growth of wastewater discharge. The water environment will be improved in main waters, and aquatic ecosystems are got to restoration.

It is widely believed that the water pollution, in first ten years or so, will continues expanding, water quality deteriorates with economic growth, but the expanding degree and extent is slower than economic growth. The trends are optimistically transferred to control water pollution effectively, and realize a "zero" or negative growth of wastewater discharge. The water environment will be improved in some extent. However, since the regional differences in economic development and urbanization, the water environment deteriorate in some parts of China, while in other parts of China, the water environment may get improvement.

5. Ecological Options for Water Pollution Management

In order to control water pollution effectively, the ecological approaches can play an importance role in the new century, in addition to traditional legal, administrative, and economic instruments.

(1) River basin and regional water pollution control planning

River basin is usually an ecologically entirety. It implies that water pollution control be managed in the basin. At the national level, according to their hydrology, and economic and social background, the comprehensive planning for each of seven main river basins should be made by combining water resource management, the water quality management, industry pollution control, agriculture pollution control, urban sewage control and treatment. The planning should put a great attention on regional cooperation in water pollution control.

(2) Non-point source pollution control based on ecosystem management

The non-point source water pollution is the main pollutant source for water environment deterioration, and what is worse, it is still ignored at present in China. Ecological research suggested that a well-designed ecosystem management, especially agricultural ecosystems and forest ecosystems, could improve their sustainability, as well as reduce greatly the nutrient losses from the ecosystems. These lost nutrients are usually the pollutants of rivers and lakes. Ecosystem management in river basin or region can nurture the nature services of artificial ecosystems, such as decomposition of organic chemicals and nutrient maintenance, and minimize the chemical fertilizer, pesticide and other pollutant discharge, and improve water quality.

(3) Total pollutant control based on purification capacity of waters

It is well known that the rivers and lakes have very big purification capacity. Within their capacity, the pollutants can be decomposed and reduced by physical-chemistry processes and biological processes. The water pollution and eutrophication can be ecologically explained as the amount of nutrients and pollutants are exceeded ecosystem's purification capacity. In order to protect water environment from pollution, it is necessary to estimate the total amount of the pollutants into waters according to ecosystem purification capacity.

(4) Clean production and ecological industry

The resource efficiency and economic feasibility of pipe-end treatment of wastewater has been argued in China. The backward industrial technology and production processes are urgently needed to replace by clean production systems. The methodology of industry ecology, applying nature principles in human system management, can be applied in clean production design for purpose making full use of resource and minimizing waste discharge.

References

1. Changming Liu and Xiwu He et al, 1996, Strategy on Water Problems in China's 21 thCentury, Science Press, Beijing.

2. Changming Liu et al. Strategies for China's Water problems in 21st century. Beijing: Science Press, 1996.

3. Hydrological Bureau, Ministry of Hydrological Engineering and Hydropower. Assessment of China's Water Resources. Beijing: Hydraulic Engineering and Hydropower Press, 1987.

4. State Environmental Protection Administration, 1998, National Annual Environmental Report.

5. National Statistics Bureau of China, 1999, China Statistics Yearbook, China Statistics Press Beijing.

6. State Environmental Protection Administration, 1998, China Environmental Statistics, China Statistics Press Beijing

7. State Environmental Protection Administration, 1997, Environmental Year Book

8. Wang, Hongchang (1998): Deforestation and Desiccation in China. A preliminary study. In: The Economic Costs of China's Environmental Degradation. Coordinators: Vaclav Smil / Mao Yushi, Project on Environmental Scarcities, State Capacity, and Civil Violence. Published by the Committee on International Security Studies, American Academy of Arts and Sciences.

9. World Bank (1997): Clear water, blue skies: China's environment in the new century. Washington, D.C.

Can China feed itself?
--An analysis of China's food prospects with special reference to water resources.

Gerhard K. Heilig Günter Fischer Harry van Velthuizen

1. Introduction

There can be no doubt that water is an important issue in China's development process. All major sectors will have increasing demand: the industry, the service sector, residential areas, and certainly the agriculture. On the other hand, the resource is very unevenly distributed, there are problems with pollution and insufficient wastewater treatment, the pricing is inadequate, and the institutional arrangements in the water supply sector need further improvement.

However, before we analyze the specific problems of water use in China's agriculture, one observation should be emphasized: In its long history, this civilization had been confronted with water shortages for centuries. Hence, the Chinese developed one of the most sophisticated systems of irrigation long before comparable schemes were implemented in the West. During the early Han Dynasty, in the fourth and third century BC, the Chinese started systematic land reclamation and irrigation schemes, converting large areas of natural land into rice paddies (Fang and Xie 1994). The process, which was systematically planned and coordinated by subsequent dynastic bureaucracies, reached a first climax already in the eleventh and twelfth centuries (Braudel 1990). While past success in water management is certainly no guarantee for the future, it still suggests a deep cultural experience with this resource. This accumulated knowledge in large groups of China's (agricultural) population – transformed into institutions and traditions – is a good starting point to master the challenges of the future. There is no need for nervous pessimism or blunt doomsday scenarios.

2. What are the core problems

While various authors have emphasized different aspects of China's water problems, most experts would probably agree that each analysis must take into account at least the following dimensions:

(1) The highly uneven spatial distribution of China's freshwater resources

(2) The strong seasonality in precipitation and – consequently – river flows

(3) The increasing discharge of untreated wastewater from industry and urban areas

(4) The insufficient capacity of urban water supply systems as compared to the rapidly increasing demand

(5) The low efficiency of traditional irrigation systems based on open canals and field flooding, if compared with high-tech irrigation schemes

(6) The lack of adequate pricing mechanisms, which would signal scarcity to the water

consumers

(7) The institutional and political frictions between various administrative levels, concerning planning, financing, construction and maintenance of water-related infrastructure, and

(8) The conflicts between different types of water use, such as hydropower generation, freshwater supply, extraction and discharge of industrial process water, irrigation in agriculture, fishery and river transport.

These water problems have already led to a number of secondary effects that clearly are a reason of great concern:

(1) Large amounts of groundwater extraction (particularly for irrigation and municipal use in the northern part of the North China plain) have caused the descending of the groundwater level and might lead to an aridification of the topsoil.

(2) There is serious eco-system deterioration in those watersheds and coastal areas, where the industrial pollution has been increasing rapidly in recent years. This affects not only the biodiversity in these areas, but threatens the fishing and/or tourist industry and the farmers who need irrigation water downstream.

(3) The construction of dams and reservoirs for irrigation, municipal use, and industry and for hydropower generation is affected by very serious siltation problems – particularly along the Middle Reach of the Yellow river. Reservoir siltation not only reduces the storage capacity (and thus the amount of possible water withdrawal), but also affects turbines and other power-generating equipment. And it clogs up irrigation infrastructure.

(4) Dams and dykes in China, which are essential for the water infrastructure, are frequently in poor condition. Up to one third of all dams are potentially dangerous and need better maintenance. On March 23, 1999 "China Daily" reported that almost 33,000 smaller and medium-sized dams would need repairs, which would require an investment of about 3.6 billion US$. A deteriorating water infrastructure has seriously increased the risk of flooding in China (which is already quite high from natural causes). Natural conditions, such as the siltation of the Yellow River, amplify these problems: there is an ongoing battle to increase the height of the dams, as the Yellow river is constantly raising its bed by sediment deposition (in some places it is some 8 meters above the surrounding area).

There are, of course, many other specific consequences of water problems in the country, but now we would like to focus on the situation in agriculture.

3. Analysis of water problems in agriculture

Climate factors, particularly precipitation, are critical for China's agriculture. Rainfall is very unevenly distributed within the country: there is more than enough in the Southeast and almost none in the West. The Xi Jiang (Pearl River) basin and delta have the highest precipitation levels in Mainland China with more than 2,000 mm per year. Very high precipitation can be also found in Guangdong province (see Map1). From high precipitation in the coastal provinces of the Southeast, rainfall gradually declines toward the Northwest of the precipitation levels in China). An area of moderate precipitation stretches from Yunnan in the south through the North China plain to the northwestern province of Heilongjiang. Most of Xinjiang and Gansu provinces and most parts of Inner Mongolia, Tibet, and Qinghai in the center are extremely dry. Average precipi tation in these provinces is usually below 200 mm per year; some areas have almost no rainfall. A critical level of precipitation is around 400 mm per year; below that level, rain-fed agriculture is usually very difficult or impossible. The orange and yellow areas in Map 2 show that precipitation in much of China's land areas is below that critical level.

Settlement patterns in China are reflecting these greatly varying precipitation levels. In Table 1 we have analyzed how many people live in areas with insufficient precipitation: In the three decades between 1958 and 1988, some 3.97 billion ha in China (or 42% of the total area) had average precipitation below 400 mm; but only 38 million people (or 3.3% of the population) were living in these areas with very low precipitation.

Thus, the great majority of the Chinese population has settled in regions, where precipitation is, in principle, sufficient for rain-fed agriculture. Actually, about 51% of China's population (589 million people) lives in areas where average precipitation is quite high – about 1,000 mm per year or above (corresponding to some 22% of the total land). The population density in these areas is between 280 and 324 people per square kilometer (see Map 1 and Table 1). This fundamental relationship between precipitation patterns and population distribution suggests that abundance of water (in the form of flooding) is likely to affect many more people in China than a lack of water. This is reflected in statistical data, which for most years in recent history indicate that more arable land areas and more people are affected by flooding than by draught (see Figure 1).

4. What is wrong with Lester Brown's alarming diagnosis of China's water shortages in agriculture?

The above conclusion might surprise those who have read Lester Brown's alarming diagnosis of China's water shortage (Brown, 1998). He argued that "China depends on irrigated land to produce 70% of the grain for its huge population of 1.2 billion people. But it is drawing more and more of that water to supply the needs of its fast growing cities and industries."(Brown, 1998, 10). And later in his paper he argues: "... in a country, where 70 percent of an even larger grain harvest (than in the US) comes from irrigated land, and where groundwater mining is widespread, the impending consequences of aquifer depletion are far greater." (Brown, 1998, 18)

These arguments suggest that China's water problems – which no one familiar with the situation would deny – actually affect the bulk of China's grain production. This is simply wrong. A significant amount of China's grain (for instance almost all of its rice) is produced in areas, where precipitation is more than sufficient for rain-fed agriculture. China's humid South and Southeast have precipitation levels that can supply the dominating paddy rice cultivation (either directly or indirectly by feeding rivers which frequently have such massive supply that they flood huge areas). The seasonality of their water flow might be a problem, but that is clearly a management problem and not one of resource scarcity. All areas south and about 200 km north of the mighty Yangtze River have – on average - more than sufficient rainfall even for irrigated agriculture.

The situation is certainly different in the rain-fed cultivation areas in the middle and northern parts of the North China plain, especially near the urban agglomeration of Beijing and Tianjin, where farmers pump up water from the groundwater table. There are also problems with those irrigation systems that are fed by the water-scarce rivers of the North, such as the Yellow River. However, these problems of dry-field irrigation in the North cannot be compared with the situation of paddy rice fields in the humid South and Southeast. In the northern part of the North China plain, a strong competition has emerged between the water consumption of industry and urban areas on one hand and the irrigated dry-field cultivation on the other hand. Here are certainly serious water resource deficits, but they clearly affect only part of China's agricultural production.

The key-questions are: How much of China's rain-fed cultivation area depends on additional irrigation for adequate productivity and how much of China's arable land reserve in the North and North East (which we have estimated in the order of 30 million hectares) can be only brought into cultivated with irrigation?

The IIASA Land-use Change Project has conducted a major study to model the (rain-fed and irrigated) cultivation potential of China. According to this research, China has a total rain-fed cultivation potential of 151 million hectares, which can produce some 521 million tons of grain (see Tables 3 and 5). This takes into account all areas in China with appropriate soil, terrain and climate conditions – in both the South and the North. The estimate also takes into account that some 5 to 15% of the suitable land will have to be reserved for infrastructure and that 25% of the suitable land will be used for non-grain crops, such as vegetables, fruits, and fiber crops. (For technical details of the study see: Fischer, / van Velthuizen, / Nachtergaele, 1999). When we used the same methodology to calculate the irrigated cultivation potential of China, we ended up with 162 million hectares – which would be equivalent to an annual production of some 652 million tons of grain (see Tables 2 and 4).

In other words: By using irrigation, China can expand its areas with cultivation potential from 151 to 162 million hectares or 7.2 percent. The grain production potential can be boosted from 521 to 652 million tons – or by 25 percent. The increase in production is, of course, higher than in area, because with irrigation the productivity on many rain-fed fields in the North and North East can be increased.

It must be emphasized that these estimates of cultivation potential in China were made with a very sophisticated Agro-Ecological-Zones (AEZ) model, which was developed by IIASA in close collaboration with FAO using the most recent biophysical and climatic databases with a resolution of 5 by 5 kilometers. The estimates show what production would be possible, if all suitable areas in China (with the exception of infrastructure and non-grain crops) would be cultivated at currently available levels of technology. The estimates are, of course, higher than the current production, because not all suitable areas are currently used, and the productivity has not everywhere reached its maximal sustainable level (especially in remote inland areas grain production productivity is still significantly lower than in the West).

From these analyses, we can conclude that water deficits might affect those 25 percent of China's grain production, which are produced on areas that either totally depend on irrigation or have significantly higher productivity when irrigated. However, that also means that some 75 percent of the crop production is not systematically threatened by water shortages – either because it is produced on paddy rice fields in humid regions (where there is certainly enough water), or because natural precipitation is still sufficient for rain-fed production.

Of course, our analysis does not imply that the agricultural regions in the South always have enough water. As anywhere else in the world, in certain years a draught may strike. There could be even multi-year draughts. However, the long-term precipitation trends for those areas that produce 75% of China's grain do not indicate a systematic water deficit. It would not be correct to extrapolate from a few dry years the imminent water crisis of China's total agriculture.

One might argue that without irrigation and water management even in the humid South the paddy rice fields could not produce its currently 2 or 3 harvests, but only 1 or 2. That is correct, but not the point of argument. We argue that in a large area in China's South and Southeast – from the coast to about halfway up between the Yangtze and Beijing – water is a management issue, not a problem of water scarcity. With proper water management, this area has usually enough water (from precipitation and river flow) to produce 2 or 3 harvests. One has to distinguish the technical water management problems in the southern half of the country from the resource scarcity problems in the north.

We think that these results of our research are supported by collateral evidence. In 1997 the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) commissioned a large study on China's freshwater resources. It was conducted in collaboration with the Nanjing Institute of Hydrology and Water Resources of the Ministry of Water Resources of China. The main results, reproduced in Table 6, indicate that all river basins in the south, south-east and south-west have more than enough water by all measures. The per capita surface water runoff ranges from 2,400 to 32,000 cubic meters. The water resources per hectare of cultivated land range from 39,300 to 327,000 cubic meters, which is certainly enough by all measures. There should also be no serious problem in the Northeast, where almost 1,480 cubic meters are available per person per year and 9,560 cubic meters per hectare of cultivated land.

Critical – according to this source – is certainly the situation in the Hai He-Luan He Basin, which covers about 11 percent of China's cultivated area and is home to some 10% of the population. Very limited surface water runoff is also reported for the Huai He / Luan He Basin and the Huang He basin. Together, these three Northern and Eastern basins account for 38.5 of the cultivated land and are home to some 34 percent of the population. While there are certainly serious problems in these areas one cannot say that agriculture has become impossible.

While Brown briefly mentioned the fact that all of China's South and the whole Yangtze basin certainly have no serious water deficits, he continues to talk about a water threat to 70% of China's grain harvest. He is ignoring the fact that at least half of these 70% of irrigated grain is produced precisely on the paddy rice fields of Southern China and the Yangtze basin. These areas produce most of the rice (in the monsoon season) and some share of the wheat in the winter.

5. What are the real water problems in China's agriculture?

It is clear that the water situation in the North and North-East of China needs careful monitoring and decisive measures to prevent a serious decline in agricultural productivity and to stop the degradation process that is already under way in the natural environment.

We believe that there are three conditions, which we have to take into account in particular when we analyze the water situation in the North:

(1) One of the major, rapidly growing population centers in China – the Beijing – Tianjin urban agglomeration – is located very close to a climatic boarder line where the long-term precipitation patterns fall below the 400 mm threshold – which is a critical level for rain-fed agriculture. Essentially all of Beijing's hinterland to the West and Northwest is more or less arid. The soaring water demand of this urban agglomeration competes with North-China's agriculture in an area of natural water-scarcity (that is a big difference to other big cities in China, such as Wuhan or Shanghai).

(2) There is a belt of extreme instability in precipitation patterns, expanding from Ningxia province to the northern part of Shaanxi, most of Shanxi, Hebei province and the eastern parts of Inner Mongolia. As can be seen from Map 3 this is clearly reflected in the Length-of-Growing Periods (LGP), which we have calculated for the period between 1958 and 1988. They strongly fluctuate from year to year in these regions – indicating that climatic production conditions are very unstable (other than, for instance in Sichuan province, which is an "island of agro-climatic stability").

(3) Siltation is the major problem in the Yellow river basin, which has a multitude of consequences. In its upper and middle reaches the sediment load of the river is filling up the water reservoirs, thus reducing their storage capacity, ruining the turbines and clogging irrigation pipes and canals. It was estimated that between 1949 and 1975 the reservoirs in the provinces of Shaanxi, Shanxi, Gansu, and Inner Mongolia lost 1.15% of their total capacity each year due to siltation (Wang, 1998). The declining capacity reduces their buffer function against the extreme seasonality of water flow in the Yellow River – which, in turn, increases the risk of flooding downstream (and reduces their hydropower potential). The alternative is not much better: with larger reservoir capacity upstream, the water flow downstream would slow down – giving the sediment load an even better chance to settle down on the ground (which, in turn, increases the risk of flooding again). There is no easy solution for the Yellow River.

With these conditions, water is certainly a major problem in North-China's agriculture. However, there are many technical, economic and administrative possibilities to deal with these problems. Some of them will be discussed below.

Irrigation efficiency is critical for saving water, since almost 66% of all water is still used in irrigation - about 343 billion cubic meters, as compared to 24 billion cubic meters in urban areas and 89 billion cubic meters in industry (see Table 7). If estimates of experts are correct, that China is wasting some 30 - 40% of its irrigation water, than China's irrigated agriculture could save between 100 and 137 billion cubic meters of water. With this saving current urban water-consumption could quadruple - at least. Of course, in practice, these water savings are unlikely; but even 10% of this amount would be equivalent to about half the current urban water consumption. These numbers show that investment into irrigation efficiency is a serious option for developing China's water resources. There are several simple technologies available. A first measure would be to invest more into the maintenance of irrigation canals, because many are in poor condition or broken. One could also seal the bottom and sides of small canals with plastic sheets, when water seeps into the ground. Pipelines, instead of open canals, would largely prevent evaporation. However, there are also more advanced technologies: For instance, low-level sprinklers or drip-irrigation might be applicable in vegetable and fruit cultivation. Here we cannot discuss all the possibilities, because they very much depend on the specific local conditions. However, there can be no doubt that the saving potential is considerable and that technology is available to realize it.

Evapotranspiration is one of the problems in dry-field cultivation. The water not only gets lost directly by evaporation from the soil, but the plants loose water from their leaves in the process of photosynthesis. When the air is dry and the wind strong this loss can be considerable. One solution to the problem is to create a more humid microclimate under a plastic cover. Covering fields with large plastic sheets protects both the soil and the plants from loosing water to the dry air. This system is quite successful in China for certain cultures. However, with modern possibilities of plant-genetics there might be also a chance for a quick break-trough in draught-resistant crops. It could pay greatly for China to invest into this research field.

Grain import is essentially equivalent to the import of water. Moreover, the import of grain would free up some of the cropland for the production of high-value and labor-intensive products, such as vegetables or fruits. This could certainly increase farmer's income and help to provide labor to the millions of rural un(der)employed. However, it is not so clear that grain imports would reduce the pressure on China's water resources, since the alternative production (vegetables, fruits, fishponds) might need even more water. Nevertheless, economic rationality certainly suggests that China should consider importing some 30 to 50 million tons of gain per year - in particular feed grain and wheat. Canada, France, the US and Australia would be more than happy to export some of their water to China (in the form of grain). By the way, there is no reason why these countries would not be able to supply China with this amount of grain. The world grain exports from Argentina, Australia, Canada, the European Union and the United States have been stagnating at about 200 million tons annually since the early 1980s – not because these countries could not produce more (as Lester Brown argues), but because of lacking demand, low prices and declining export subsidies. The European Union has been fighting over-production for many years – farmers are still being paid real money for taking fields out of production.

6. Conclusions

There is a great diversity of water conditions in China: in some places, water is abundant; in others, people face severe shortages. In a large belt from the South-central to the North-east precipitation is extremely seasonal – in some years, all the rain falls in a few days, washing away the topsoil instead of soaking the soil. In the Loess Plateau water erodes the arable land and downstream, in the Yellow river basin people fight the problems of siltation. In some other places industry and urban discharges pollute the water for irrigation. In up-stream areas, farmers (and other users) often waste the water, while in the downstream provinces these rivers completely fall dry. These specific water problems can be only analyzed (and solved) on a case-by-case basis, taking into account local and regional conditions.

The intention of this paper was a different one. We were interested in strategic issues at the national level that can be summarized in the following question: "What are the key-measures the Chinese government should initiate to improve the water security of various users in coming decades – including agriculture?" Based on our models and analyses we believe that the following three measures are the most important:

First, effective pricing mechanisms for freshwater consumption must be implemented and / or improved. Adequate water allocation between competing users is impossible, without a clear price signal. All efforts to improve efficiency in irrigation, in the industry or in private households are doomed, if water is considered essentially a free resource. Obviously, the problem is that poor farmers in arid regions, who need water for irrigation, cannot afford to pay the same price as rich coastal cities. Some kind of government regulation is therefore inevitable to protect poor segments of the population and economy from the booming water demand of rich urban areas. Various schemes to raise the price of water are possible, such as a water tax with different rates for farmers, industry and urban consumers.

Second, almost everywhere in the country water technology and infrastructure must be modernized, if China wants to avoid running into big problems in coming decades. In particular, China needs a strategic initiative to introduce and expand modern water supply and sewage systems in all its rapidly growing urban areas and towns. With further economic development, China – as any other country in the world – will experience a "sanitary revolution". Residential water consumption will surge, when more and more people are using washing machines, kitchen sinks, flush toilets, and bathrooms in their apartments. Better technology is also necessary to clean-up wastewater discharge from industry and mining. The biggest improvement, however, could be achieved with more efficient irrigation methods, since China still uses most of its water in agriculture. Many experts have estimated water losses of up to 40% due to evaporation and leaky canals. China has a sea of water in its conservation potential. China must also increase its efforts to build new reservoirs that are needed as a buffer against the extreme seasonality of river flow and/or precipitation. Existing reservoirs have to be cleaned from sediment. Finally, integrated hydrological control schemes consisting of dams, reservoirs, reserved flood plains, and advanced monitoring and early warning systems could reduce the risk of flooding – one of the biggest threats to China's agriculture.

Third, the trans-basin water diversion from the South (Yangtze) to the North and the North-Central provinces is inevitable. According to our detailed geo-biophysical and climate assessment (in the AEZ model) we believe that China has some 30 million hectares of arable land reserves - in addition to its 132 million hectares of currently cultivated land. These land reserves are – in principle - suitable for crop cultivation according to their soils, temperature profile and terrain conditions. Unfortunately, about 60% of these reserves are located in areas, where natural precipitation is insufficient (and would lead to very low yields or prevent cultivation altogether). However, with adequate and carefully managed irrigation these areas, which are mostly located in the North-central and Northeast, could be used for sustainable crop production. There are also many currently cultivated areas in the Northern half of the North China plain, which would benefit from a better water supply. Since pumping-up of groundwater is not a long-term alternative (the demand is higher than the renewable resource) water diversion from the water-rich South is the only alternative. While the specific schemes that are currently implemented might be problematic (because of their serious environmental consequences), the basic idea is sound. Why should China not develop its North with water from the South - just the same way as the US has developed California with water from the North? Phoenix – a booming city in the middle of a desert, was the most rapidly growing urban area in the United States in the last decades. China needs water in the

North not only for its agriculture, but also for the rapidly growing urban-industrial agglomeration of Beijing-Tianjin.

Based on our AEZ model we believe that China has the biophysical potential to produce roughly 520 million tons of grain, if all currently cultivated areas are used and additional land reserves are taken into cultivation. This could be achieved with current technology based on current agro-climatic conditions (soils, temperature and precipitation profiles, terrain). If irrigation would be available for all those areas, where the water balance is not sufficient, China could increase its maximum potential production to about 650 million tons of grain. This indicates, that even based on rain-fed cultivation alone (which is possible in large areas of the South) China could feed a 1.5 billion population (perhaps not easily, but it would be possible). With adequate irrigation, however, the safety margin would be quite comfortable. This shows that the development of sustainable water resources is a important issue for China's food security.

Braudel, F. (1990): Sozialgeschichte des 15.-18. Jahrhunderts. Der Alltag. München (Kindler Verlag). Original: Civilisation matérielle et capitalisme, XV-XVIII siécle. Le structures do quotidien: Le possible et l'impossible. Paris, 1979

Brown, L.R. / Halweil, B. (1998): China's Water Shortage Could Shake World Security. World Watch, Vol. 11, No. 4, July / August, 1998

Fang, J.W. / Xie, Z. (1994): Deforestation in pre-industrial China: The Loess Plateau as an example. In: Chemosphere, Vol. 29, 983-999.

Fischer, G. / Heilig, G.K. (1997): Population Momentum and the Demand on Land and Water Resources. In: Philosophical Transactions of the Royal Society of London B, Vol. 352, 869-889

Fischer, G. / van Velthuizen, H. T. / Nachtergaele, F.O. (1999): Global Agro-Ecological Zones Assessment: Methodology and Results. Laxenburg (Interim Report, IR-98-110), Laxenburg, Rome (IIASA, FAO)

Menenti, M. (1997): Regional water resources management and land surface processes in northwestern China. In: Proceedings Workshop Wageningen-China, Wageningen, May 13, Agricultural Research Department, Research Institute for Agrobiology and Soil Fertility.

United Nations. Economic and Social Commission for Asia and the Pacific [ESCAP] (New York) (1997): China: Water resources and their use. Study on assessment of water resources of member countries and demand by user sectors.

Wang, Hongchang (1998): Deforestation and Desiccation in China. A preliminary study. In: The Economic Costs of China's Environmental Degradation. Coordinators: Vaclav Smil / Mao Yushi, Project on Environmental Scarcities, State Capacity, and Civil Violence. Published by the Committee on International Security Studies, American Academy of Arts and Sciences.

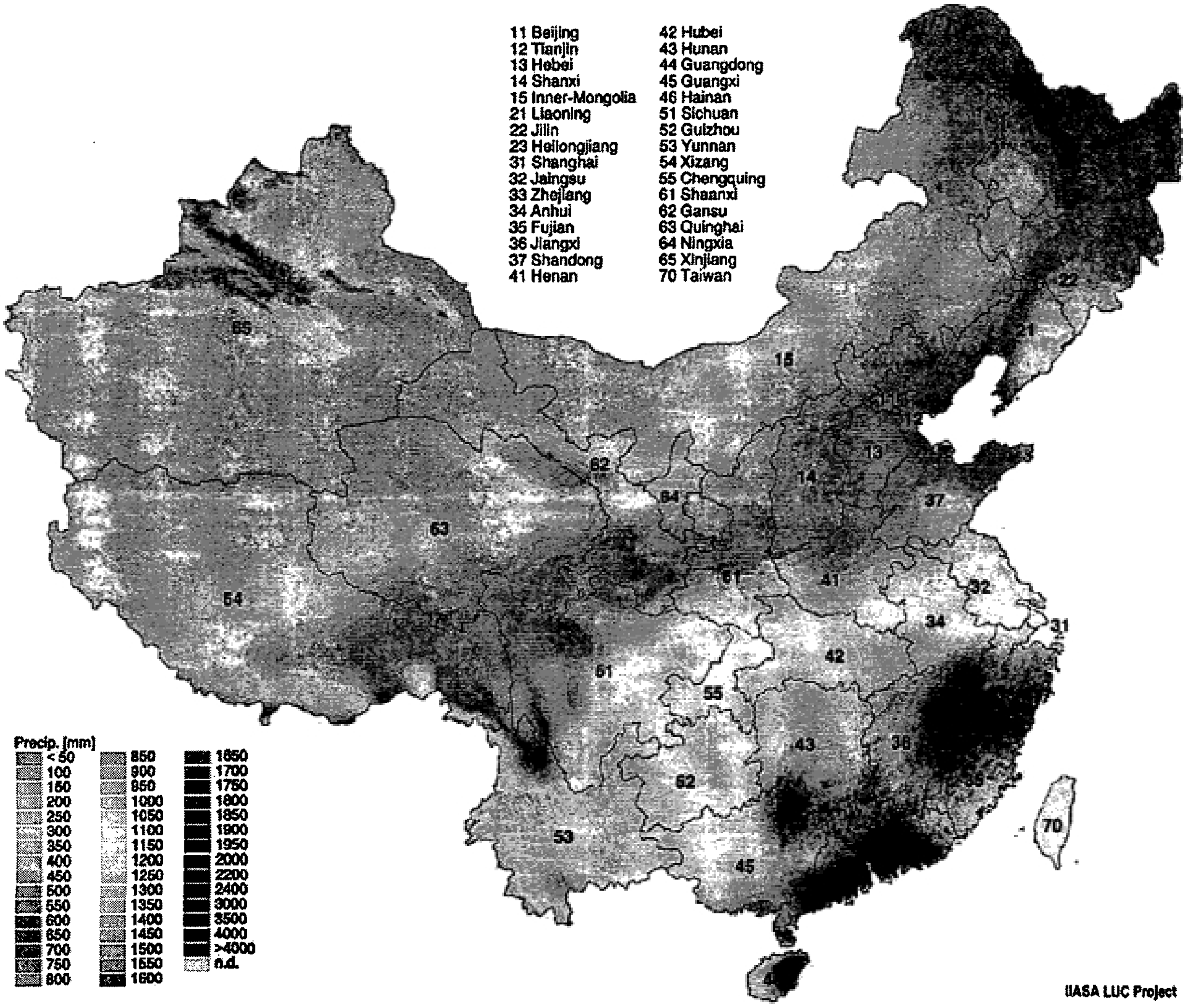
World Bank (1997): Clear water, blue skies: China's environment in the new century. Washington, D.C.

Map 1: Average annual precipitation in China, 1958 - 1988

Primary data sources used: Leemans, R. and W. Cramer, 1991, The IIASA database for mean monthly values of temperature, precipitation and cloudiness on a global terrestrial grid, IIASA

Report, RR-91-18, Laxenburg, 63pp.; Inst. of Soil Science, Accademia Sinica, 1986, The Soil Atlas of China, Cartographic Publishing House, Beijing, p. 6

Map developed by IIASA LUC-Project. Primary Data Sources: (1) State Land Administration of the People's Republic of China / United Nations Development Program / State Science and Technology Commission of the People's Republic of China / Food and Agricultural Organization of the United Nations: Land Resources - Use and Productivity Assessment in China. Project CPR/87/029, Beijing, 1994. (2) Institute for Remote Sensing Applications: Land-cover map of China. Beijing, 1994



Map 2: Share of irrigated land in China's cultivated areas.

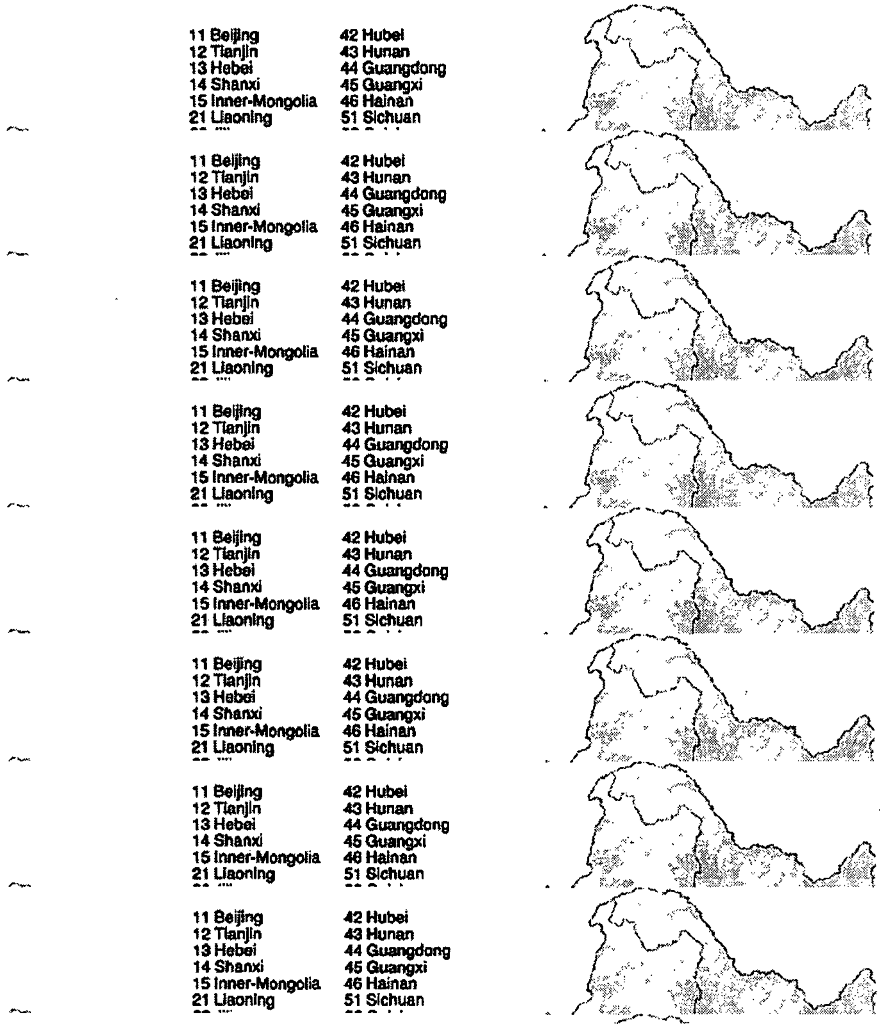


Table 1: Population and Land Area in China by Precipitation Zones, Average for 1958– 1988

Precipitation (mm)	Area (sqkm)	Area (% of Total)	Population (millions)	Population (% of Total)	Population Density
2000-4000	36,350	0.4	12	1.0	324
1000-2000	2,064,700	21.9	577	49.8	280
800-1000	544,000	5.8	148	12.8	272
600-800	986,075	10.4	214	18.5	217
400-600	1,845,250	19.5	170	14.7	92
200-400	1,229,225	13.0	24	2.1	20
< 200	2,742,900	29.0	14	1.2	5

Source: IIASA LUC-GIS

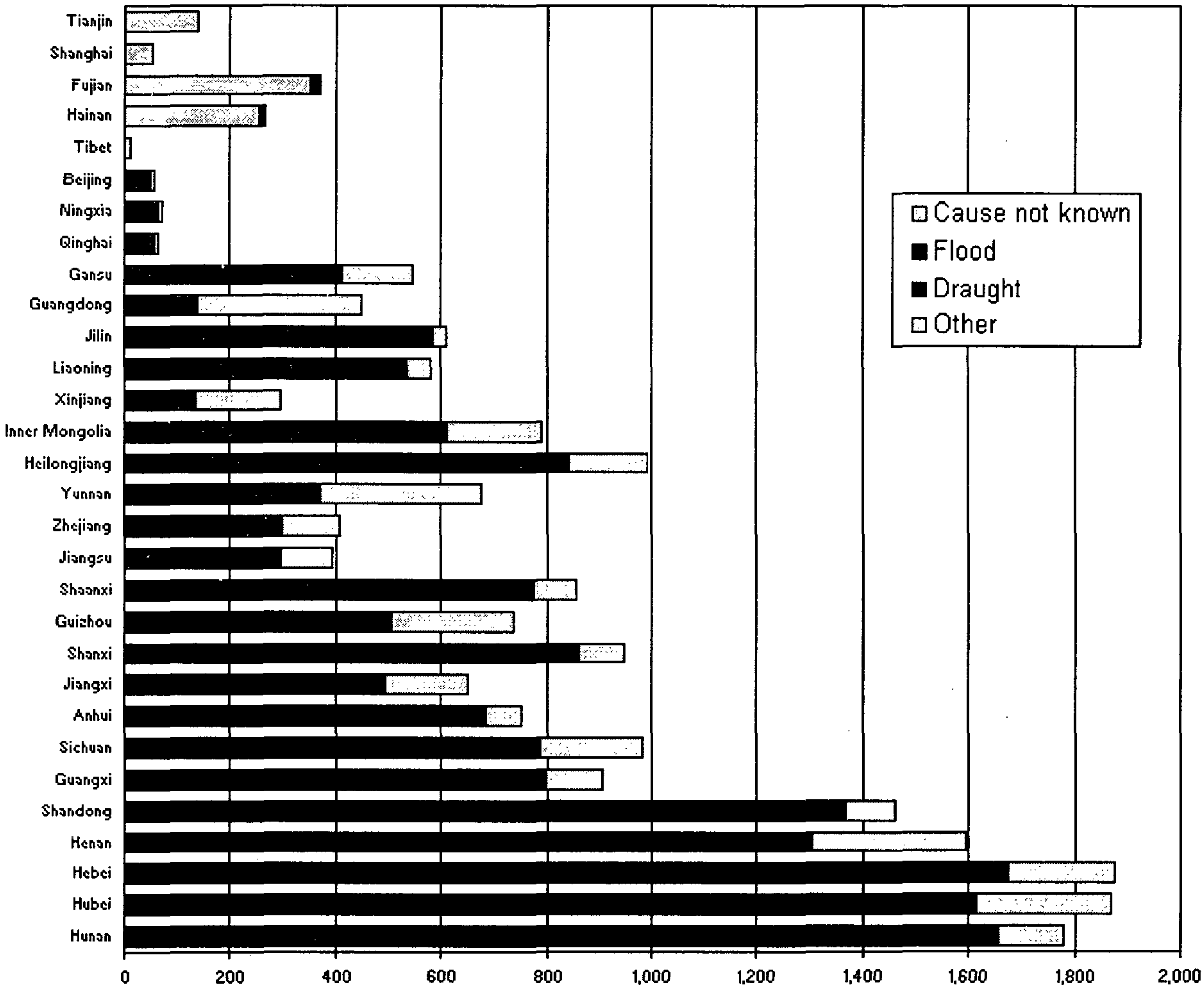
The table should be read as follows: About 50% of the Chinese population of 1992 (or 589 million) lived in some 22 of the total land area, in which average annual precipitation between 1958 and 1988 was between 1000 and 2000 mm per year (in some small areas it was even up to 4000 mm). The population density in these areas was between 280 and 324 people per sqkm.

From the table we can also see that roughly 97% of the population lives in areas, where average precipitation over the three decades between 1958 and 1988 was 600 mm per year or more. This precipitation level is usually sufficient for rain-fed agriculture (provided that the timing of the rain is adequate for cultivation or that water storage systems are in place for buffering seasonal variation).

If we consider precipitation levels of more than 400 mm as still adequate for some kind of rain-fed agriculture (with a low level of productivity), we find that almost 99% of the Chinese population lives in these areas. While there are some places in the world where agriculture is successfully practiced at such low precipitation levels, it is clear that the range between 400 and 1000 mm is difficult for cultivation.

To be on the save side, we can say that roughly 5 - 10% of the Chinese population lives in areas, where precipitation levels are so low that rain-fed agriculture is difficult or impossible. This first crude estimate is confirmed by our more detailed LGP-estimates in the AEZ model (which take into count several other climate factors, such as minimum and maximum temperature, sunshine duration, frost-free days, wind speed, etc.).

Figure 1: Areas affected by natural disasters by province, 1996 (1,000 ha)



Source: China Statistical Yearbook, 1997, State Statistical Bureau, People's Republic of China, Beijing, China, p.397.

Note: For Tianjin and Shanghai, only total area affected by disasters was available. For Fujian and Hainan, only total disaster area and area affected by droughts were available. For Tibet, only total disaster area and area affected by floods were available.

Table 6: Surface water runoff and availability in China, 1993 (% of national total)

River System	Region	Waterresources (%)	Population (%)	Cultivatedland (%)	Per capita water resources(cubic meter per year per person)	Water resources per hectare cultivated land (cubic meter per year per hectare)
I	Northeastern	6.9	10.0	19.8	1,479	9,560
II	Hai He-Luan He Basin	1.5	10.0	10.9	225	3,760
III	Huai He Basin	3.4	16.0	14.9	389	6,310
IV	Huang He Basin	2.6	8.0	12.7	656	5,730
	II + III + IV	7.5	34.0	38.5		
V	Chang Jiang Basin	34.2	34.0	24.0	2,369	39,300
VI	Southern	16.8	12.0	6.8	3,465	67,950
VII	Southeastern	9.2	6.0	3.2	2,999	73,800
VIII	South--western	20.8	2.0	1.7	31,679	327,000
	V + VI + VII + VIII	81.0	54.0	35.7		
IX	Interior Basins	4.6	2.0	5.8	4,832	21,850
	National total	100	100	100	2,323	28,000

Source: United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) (1997): Study on Assessment of Water Resources of Member Countries and Demand by User Sectors: China - Water Resources and Their Use. New York, p. 9

Table 7 (a) : Water use by economic sector in China, 1993 (billions of cubic meters)

Basin System	Region	Industry	Urban water supply	Agriculture				Total
				Irrigation	Forestry pastures fishery	Rural water supply	All agriculture	
I	Northeastern	9.90	2.66	33.13	2.75	1.39	37.27	49.83
II	Hai He-Luan He Basin	6.82	3.62	27.47	1.59	1.76	30.82	41.26
III	Huai He Basin	6.08	2.29	39.86	4.71	3.97	48.54	56.90
IV	Huang He Basin	4.86	2.07	29.88	1.95	1.42	33.25	40.18
V	Chang Jiang Basin	40.92	7.23	101.00	7.35	7.71	116.06	164.16
VI	Southern	13.88	4.22	48.00	2.25	4.31	54.56	72.66
VII	Southeastern	4.61	1.36	20.21	0.97	1.75	22.93	28.89
VIII	Southwestern	0.33	0.09	4.83	0.81	0.38	6.02	6.44
IX	Interior Basins	1.45	0.56	38.97	16.80	0.45	56.22	58.23
	National total	88.85	24.10	343.23	39.18	23.14	405.72	518.70

Table 7 (b): Water use by economic sector in China, 1993 (% of total)

Basin System	Region	Industry	Urban water supply	Agriculture				Total
				Irrigation	Forestry pastures fishery	Rural water supply	All agriculture	
I	Northeastern	19.9	5.3	66.5	5.5	2.8	74.8	100.0
II	Hai He-Luan He Basin	16.5	8.8	66.6	3.9	4.3	74.7	100.0
III	Huai He Basin	10.7	4.0	70.1	8.3	7.0	85.3	100.0
IV	Huang He Basin	12.1	5.2	74.4	4.9	3.5	82.8	100.0
V	Chang Jiang Basin	24.9	4.4	61.5	4.5	4.7	70.7	100.0
VI	Southern	19.1	5.8	66.1	3.1	5.9	75.1	100.0
VII	Southeastern	16.0	4.7	70.0	3.4	6.1	79.4	100.0
VIII	Southwestern	5.1	1.4	75.0	12.6	5.9	93.5	100.0
IX	Interior Basins	2.5	1.0	66.9	28.9	0.8	96.5	100.0
	National total	17.1	4.6	66.2	7.6	4.5	78.2	100.0

Source: Nanjing Institute of Hydrology and Water Resources (1996): Report on the mid- and long-term plans for water demand and supply in China. Nanjing (cited from: UN Economic and Social Commission for Asia and the Pacific (ESCAP): Study on Assessment of Water Resources of Member Countries and Demand by User Sectors: China - Water Resources and Their Use. New York, 1997

Local Scale Implications of the World Water Scenarios: A Case Study of Water Management in the Yellow River Basin in China.

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1. Introduction

Strzepek et al (2000) have presented a regional disaggregation of the driving forces of the three world water scenarios. The main features of each scenario is summarized below.

(1) Business-as-Usual (BAU)

Current water resource management policies continue. Population growth, economic development and technological change remain in line with UN-family predictions.

Today's problems: low access to water supply and sanitation; tomorrow's problem: insufficient food production; and the long-term problem: environmental degradation - do not get resolved.

The limits of natural and socioeconomic systems are reached by 2025. Increasing scarcity of renewable and accessible water resources and diminishing water quality further narrow the resource base of healthy ecosystems. At best this leads to chronic problems, but catastrophes may trigger regional and even global crises.

(2) Technology, Economics & the Private Sector (TECH)

Water is priced and water-rights are made tradable in order to improve equity, efficiency and sustainability.

The water sector expands, higher prices lead to increased investments, accelerated R&D and an increasing role for the private sector.

Social and ethical debates about use of new technologies are resolved. Biotechnology, information technology, desalination and improved water management increase water productivity. Irrigated areas are expanded, storage is increased, human water use goes up considerably.

International institutions remain unchanged; poor countries and poor groups within countries risk being left out of globalization. Absolute poverty decreases but income inequalities grow. The environment suffers.

(3) Values and Lifestyles (VALUES)

Education is a key pathway to developing sustainable values and lifestyles. Emphasis is on changing institutions and management, nationally and internationally

Community-level action drives watershed management, rainwater harvesting and focuses on increasing mean yield levels in irrigated and rainfed areas. Decision-making in the water sector is transparent and involves all stakeholders.

Ecological functions are recognized and maintained. Human water use is made sustainable.Projections of water demand in the agricultural, energy, industrial and domestic sectors are made based on the projections of the social and economic driving forces for the 18 regions. Assessments of regional water stress and population under water stress as well as population in hunger are made for 2025 for the BAU, Technology, and Values Scenarios. While the results provide insights into water stress in 2025 in these broad geographical regions, the scale of the analysis has the potential to mask some local critical problems or "hot spots". Alcamo, et al (2000) has performed a global water stress analysis for the three world water scenarios at the river basin and national scale. This analysis however, has not taken the water management or economic systems into account.

To complement these two analyses and provide a local scale analysis of the implications of the three water vision scenarios, three case study analyses were undertaken and are reported on here.

2. Water Management in the Yellow River Basin in China

(1) Background to the Study Region

The Yellow River (Hwange He) is the second longest river in China. The headwaters begin in the Central Western region of the Bayankala Mountains and flows eastward passing through several rural and urban regions and emptying into the Bo Hai Sea. The total length of the Yellow River is 5,464 kilometers, which drains an area of approximately 745,000 sq. km and is subjected to large variations in geology and land use. The population in the basin is estimated to be 120 million people as of 1999.

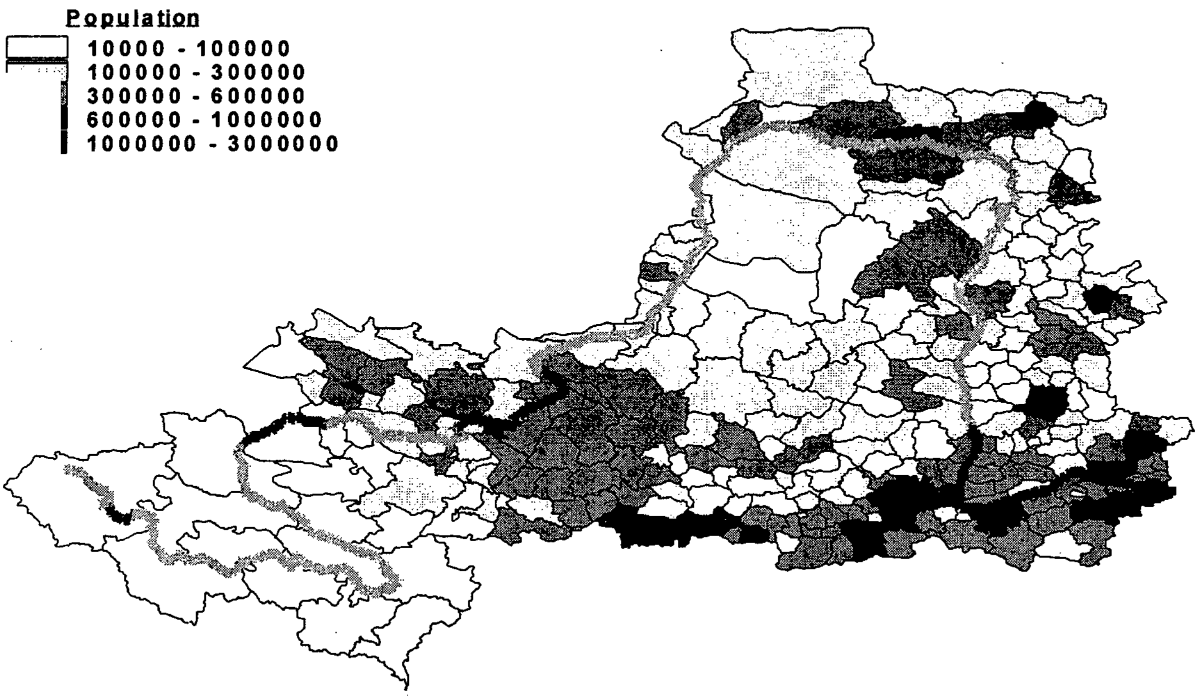
The headwater segment of the basin starts where the Bayankala Mountains form the divide between China's Yellow River on its north and Yangtze River on its south. Continuing northward the Yellow River enters the Ningxia Plain and into the city of Yinchuan. This region is one of the primary agricultural areas of the upper of the Yellow River basin due to the ability of Yellow river water to be used for irrigation through gravity-fed canals. At the downstream end of the irrigated plain the water flows through the industrial city of Wuhai. Water problems, especially heavy metals, have been a known concern in this region. Turning eastward, the Yellow river enters another major irrigated area. The fertile Hetao Plain of Inner Mongolia is bounded by the Welanbuhe Desert to the west, the Kubuqi Desert and the Eerduosi Plateau to the south, and the Yinshan Mountains to the North. Albeit isolated from mainstream China, this agricultural region has prospered from irrigation infrastructure since the sixth century. Direct diversion from the Yellow River to this agricultural region does however, leave the prosperity of its inhabitants vulnerable to flooding and drought conditions. Furthermore, these conditions have led to waterlogging and salinity problems due to drainage difficulties.

After this southward turn, the river enters the narrow gorge creating the border of the Shaanxi and the Shanxi provinces. In this gorge, the runoff from the highly erodible loess plateau flows into the Yellow River, contributing over 90% of the sediment, which gives the river its name. A predicted annual erosion rate exceeding 1,000 metric tons per km^2 in this plateau leads to the average 37 kg of sediment per cubic meter of water. After passing through narrow gorges and accumulating extreme amounts of silt, the Yellow river passes over the Hukou cascades and is met by the large Fen He tributary. In these in these final narrow canyons, several hydropower facilities are proposed. As of 1999, only the Tianqiao facility is in operation, and the Wanjiazhai dam is under construction. Six additional reservoir sites are proposed for this region. Within 100 km after the Fen He tributary joins, the Yellow River makes a sharp turn to the east and merges with the large Wei He tributary. The region downstream of the eastward turn has seen extensive historical flooding. After passing the damn at Sanmenxia, the river flows into the City of Zhengzhou. This city marks the downstream extent of natural river system. From here to the Yellow Sea the river is confined in the extensive levee structure that lines the river downstream of this point. Furthermore, the river has actually been artificially elevated above the surrounding surface land by the continuous construction of these levees over the past three millennia.

Human populations have existed since prehistoric times throughout the Yellow River Basin. Often called the "Cradle of Chinese Civilization" this basin has revealed evidence of inhabitants from Neolithic societies dating 6000 to 9000 years ago. Today, approximately 120 million people inhabit the Yellow River basin.

The vast majority of people live in the southeastern region of the basin. Less than 5 people per square kilometer inhabit the headwater regions of the upper basin. Sparse crop agriculture and mining are the primary activities of the inhabitants. Crops such as wheat, highland barley, millet, rice, potatoes, rape, broad beans, and peas are produced by these farmers. Mineral resources of coal, petroleum, salt, sylvite, lead and zinc are know to be found throughout Quinghai. Large numbers of 'large livestock' are reported throughout the upper basin counties (Ceisin 1991). As the river nears the city of Xining, county population densities increase to over 1600 people per square kilometers in Xiningshi and over 100 per square kilometers in the surrounding regions. See figure 1.

Figure 1 Population by County in the Yellow River Basin



Counties throughout Gansu are major livestock producers, particularly hogs and cattle. Further north the river flows through the Ningxia agricultural region with three cities of Yinchuan, Shizuishan and Wuhai. . Products from this concentrated region include wheat, millet, potatoes, corn, sorghum, broomcorn millet, rape, soybeans, flax, hemp, plaster stone, salt, and iron.

In the northernmost reaches of the Yellow River, the irrigated agricultural region of the Hetao Plain have population densities ranging from 30 to 200 people per square kilometer according the census statistics (Wheeler, 2000). The two major tributaries of the Yellow river are the Fen He and the Wei He. Both of these valleys sustain large populations and major municipalities. Tianshui, Baoli, Xianyang, Xi'an, Weinan are all substantial cities along the Wei Tributary. Xi'an is the largest of these cities with approximately 3 million people. Population densities throughout the Wei He Basin are shown to be between 200 and 6200 people per square kilometer throughout most counties. The Fen He tributary hosts the major cities of Yuncheng, Linfen and Taiyuan. This region is noted to have population densities ranging from 200 to 700 people per square kilometer through most of its lower counties. High numbers of livestock are also recorded throughout this region. Agricultural products of these central valleys include wheat, corn, sorghum, millet, potatoes, soybeans, sesame, peanuts, rape seed, cotton and silk cocoons. Mining in this region also yields coal, iron, graphite, salt, molybdenum and copper.

Cities along the Yellow River include Sanmenxia, Luoyang, and Zhengzhou. Population densities through this reach range from 200 to 2200 people per square kilometer according to county statistics. Agricultural and industrial activities are heavy and varied throughout this populated region.

(2) Methodology

(i) Modeling Water Demands for Agriculture

Crop water demands for corn and soybeans have been estimated with dynamic process crop growth models and an irrigation management model. CERES-Maize (Jones and Kiniry, 1986) and SOYGRO (Jones et al., 1988) are process-based mechanistic models that describe daily phenological development and growth in response to environmental factors (soils, weather and management). The crop models have been calibrated and validated over a wide range of agro-climatic regions (Rosenzweig and Iglesias, 1994).

A geographically explicit crop data base was created defining crop type and variety; time of sowing, anthesis, and harvesting; crop management; and simulated and actual production..

The ratio between actual crop evapotranspiration and potential evapotranspiration (Kc) from the CERES and SOYGRO models, monthly potential evapotranspiration and monthly precipitation were used as inputs to CROPWAT, an empirical irrigation management model developed by the United Nations Food and Agriculture Organization (FAO) to calculate regional crop water and irrigation requirements from climatic and crop data (CROPWAT, 1995).

(ii) Water Accounting and Evaluation

The balance of water demands and supplies for the study regions is undertaken in the Water Evaluation and Planning (WEAP) model, a model produced and maintained by the Stockholm Environment Institute (Boston). The model version used in this study is System Version 97.7, available from http://www.tellus.org. The WEAP model uses a nodal structure, which is specified for each study area, to account for water demands and supplies. The WEAP model allocates water demand to a set of uses according to rules chosen by the analyst. The resulting allocations can be evaluated in economic or other terms.

The nodal structures for the case study areas are shown in Figures 2. These represent the demands and sources in each of the water regions. The WEAP model is used in this study primarily to evaluate water region balances, so that the water supply in each water region is conceived as a single unit representing available flow. Demands are assigned priorities (municipal and industrial over agriculture, in the runs to date), and demands are met first through river flow and then through available storage. Demand priorities can easily be shifted in WEAP to reflect a variety of other allocational systems.

Water demands for non-agricultural uses. Water demands for non-agricultural uses have been structured within the framework of the WEAP model based on economic and population data obtained for the study regions Municipal demands are based on population forecasts and water use coefficients. Industrial demands are based on GDP forecasts and an initial estimate of

续表：

	GDP Industry (PPP)			Thermal-Electrical Generation		
	1995 (10^9)	2025 (10^9)	Rate	1995 (1000GWh)	2025 (1000 GWh)	Rate
BAU	1784	4994	3.49%	823.9	2246.5	3.40%
TECH	1784	5483	3.81%	823.9	4275.3	5.64%
VALUES	1784	5965	4.11%	823.9	4948.2	6.16%

Table 2: China Regional Driving Forces: Nutrition and Food Security

	1.1 Calories/capita/Day			1.2 Animal Products		
	1995	2025	Rate	1995	2025	Rate
BAU	2985	3096	0.12%	10%	13%	1.07%
TECH	2985	3166	0.20%	10%	16%	1.76%
VALUES	2985	3189	0.22%	10%	16%	1.76%

	FSS WHEAT &CG			FSS RICE			FSS OTHER		
	1995	2025	% Change	1995	2025	% Change	1995	2025	% Change
BAU	0.59	0.59	0%	0.96	0.96	0%	0.7	0.7	0%
TECH	0.59	0.43	-27%	0.96	0.94	-2%	0.7	0.69	-1%
VALUES	0.59	0.44	-25%	0.96	0.94	-2%	0.7	0.69	-1%

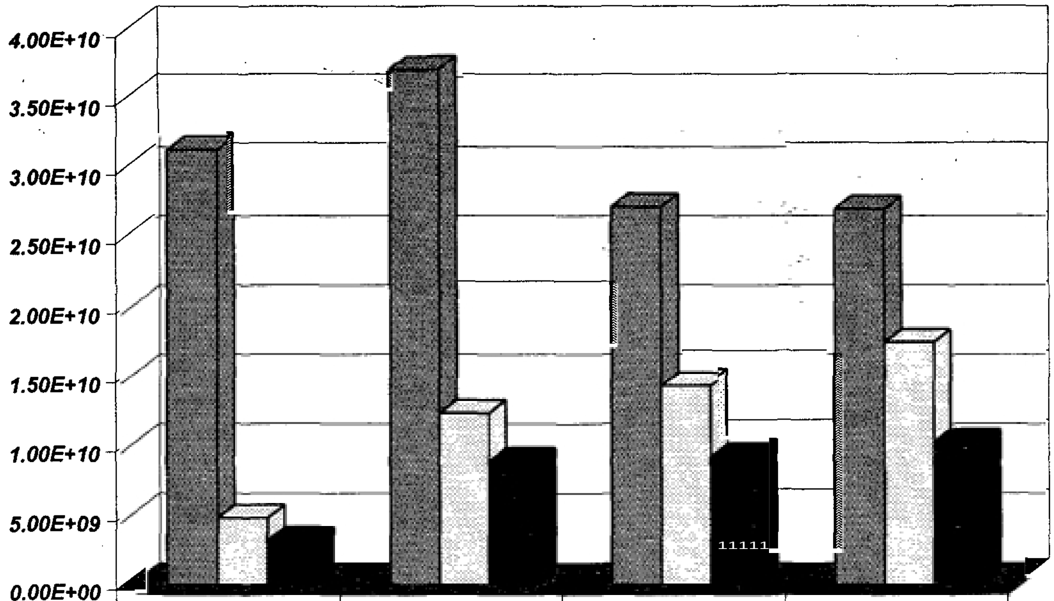
Results of the Regional Water Stress analysis for the China region using the Polestar Model are presented in Table 3.

Table 3. China Regional Water Stress Results

China		1995	BAU	Market	Values
Total Water Use	Million Cubic Meter	591,725	772,763	773,523	734,995
Agricultural Use	Million Cubic Meter	447,753	472,525	442,328	328,727
Industrial Use	Million Cubic Meter	17,881	40,991	26,559	65,319
Energy Use	Million Cubic Meter	67,405	147,030	191,216	221,309
Domestic Use	Million Cubic Meter	58,686	112,217	113,420	119,640
Demand/ Supply Ratio		15%	19%	19%	18%
Population under Water Stress	Million persons	399.63	785.53	771.06	666.90
Population in Hunger	Million persons	211.21	143.28	207.44	14.46

4. Results

The first aspect of the analysis is to examine the impacts of the scenario driving forces on the water demands in the Yellow River Basin. Figure 4 presents the results. In all scenarios there is significant increase in the industrial and domestic sectors of over 200% Irrigation water withdrawal increase by 18 % for the BAU over 1995 levels. For the Tech and Values scenarios irrigation withdrawals decrease by 13%.



	1995	BAU	TECH	VALUES
AG	3.14E+10	3.73E+10	2.73E+10	2.71E+10
IND	4.86E+09	1.24E+10	1.44E+10	1.75E+10
DOM	3.24E+09	8.92E+09	9.26E+09	1.03E+10

Figure 4 Yellow River Water Withdrawals by Sectors

These sectoral increases lead to increases in total withdrawals over 1995 for scenarios of

48%, 29%,and 39% for the BAU, TECH, and VALUE scenarios respectively. These results are illustrated in Figure 4.

Total System reliability for each scenario is shown in Figure 5. The modeling result show almost no change in reliability even thought there are significant changes in water withdrawals. Figure 6 presents the sectoral reliability results. It show the domestic sector with first priority getting 100% reliability for scenarios. Industrial reliability the second priority drops from 100% to 97% in the VALUES scenario. Agricultural, the last priority, shows a decrease from 92% in 1995 to 88% for the VALUES scenario.

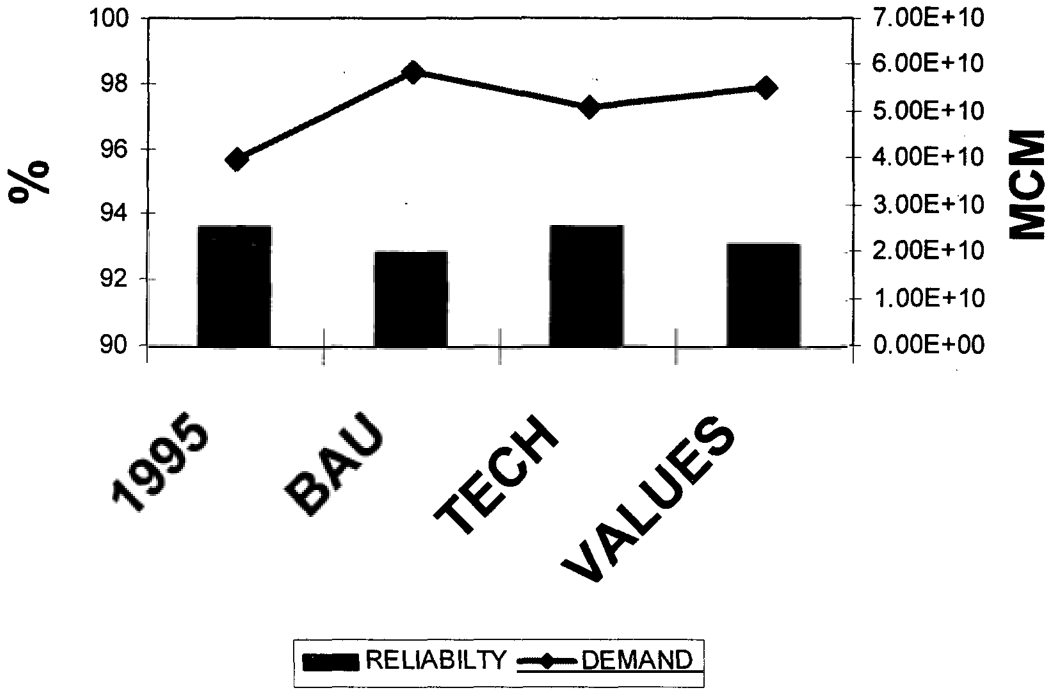


Figure 5 Yellow River Total Withdrawals and Demand Reliability

5. Implications

There are four key findings from these results that have implications for river basin planners in China and globally.

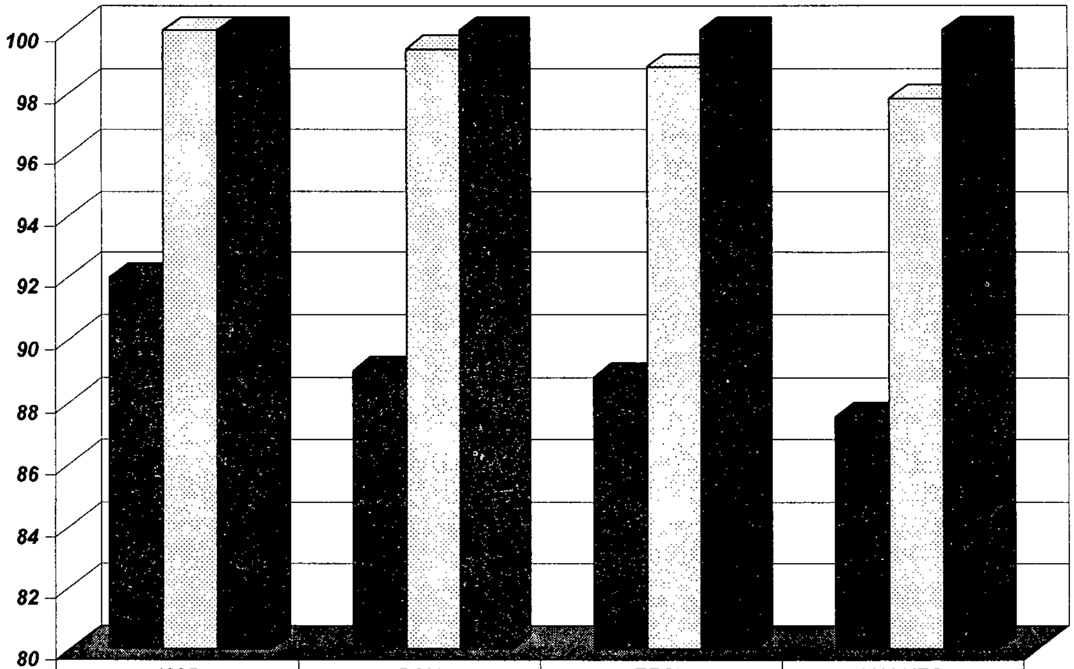
(1) With water withdrawals increasing from 29 to 48 % there was almost no change in total system reliability. This is due to the consumptive nature of the demand and the concept of basin efficiency. The major reason for the reduction in agricultural withdrawals is the increase in irrigation efficiency. This however does not effect crop consumption so return flows are available downstream for later withdrawals, with increase efficiency the water remains in the stream for later use rather first be applied on the field . So river basin reliability of Basin efficiency the total basin water consumption divided by total available water may be a better measure

(2) Increase water use by the industrial and domestic sectors is not very consumptive by leads to water quality problems.

(3) Infrastructure matter. The role of reservoirs to provide a steady yield , dampening the year to year variability in flow. Without reservoir storage reliability levels would be one –half of those reported

(4) Institutions matter. The priority of supply water to various sectors is a policy level

decision made by regional official. The nature of the water basin management system, local, county or a regional river basin authority will have major impacts on the maintaining of the overall priority of water uses.



	1995	BAU	TECH	VALUES
■ AGRIC.	92	89	89	88
□ INDUST	100	99	99	98
■ DOMESTIC	100	100	100	100

Figure 6: Yellow River Sectoral Reliability

6. Summary

The case study was presented to show the local scale impacts of the world water scenarios. The case study provided a message that large scale regional assessment can mask the true nature of local water problems. In China when water management in looked at in a river basin setting with modeling of the infrastructure, the regional scale impacts are much less at the local level than the regional analysis would have suggested..

The message is to model the water resources system at the lowest practically possible length and time scales. However, Global analyses can provide some broad level continental scale insights into water management and regional vulnerable to climate fluctuation.

References

Alcamo, J, S. Hendridx, and P. Dall, 2000. *Analysis of three water scenarios with WaterGAP* – Central Analysis Volume, World Water Vision Unit, Paris, France.

Blackie, R. *Water Issue in Nambia,*1998 Popnet, Fall 1998 Volume. International Institute for Applied Systems Analysis, Laxenburg, Austria.

CROPWAT. 1995. A computer program for irrigation planning and management. FAO Irrigation and Drainage Paper No. 46. *CROPWAT Version 5.6* (1991). FAO, Rome, Italy.

Jones, J.W., K.J. Boote, S.S. Jagtap, G. Hoogenboom and G.G. Wilkerson. 1988. *SOYGRO V5.41: Soybean Crop Growth Simulation Model. User's Guide*. Florida Agr. Exp. Sta. Journal No. 8304. IFAS. University of Florida. Gainesville, FL.

Jones, C.A. and J.R. Kiniry (eds). 1986. *CERES-Maize: A Simulation Model of Maize Growth and Development*. Texas A & M University Press. College Station, TX. 194 pp.

Gallopin, G. and F. Rijsberman. 1999. *Three Global Water Scenarios*, World Water Vision Report, World Water Vision Unit, Paris, France

Repetto, R,, 1985, *The Global possible : resources, development, and the new century* / edited by Robert Repetto. Yale University Press, New Haven, Connecticut

Rosenzweig, C. and A. Iglesias. 1994. *Implications of Climate Change for International Agriculture: Crop Modeling Study*. U.S. Environmental Protection Agency. EPA 230-B-94-003.

Shiklmanov, I. 1999. *Global Water Use Supply Data Base*, World Water Vision Report, World Water Vision Unit, Paris, France

Stockholm Environment Institute--Boston, and Tellus Institute, *WEAP: Water Evaluation and Planning System, User Guide for Version 97.0,* Boston, MA, January 1997.

Strzepek, K, A. Holt, Eric Kemp-Benedict,Paul Raskin,Gilberto Gallopin,Frank Rijsberman ***Regionalization and Implications of the World Water Scenarios***– Central Analysis Volume, World Water Vision Unit, Paris, France.

Wheeler, K. 2000. A Methodology for Rapid Water Quality Assessment: A case study of the Yellow River. Unpublished Master's Thesis, University of Colorado at Boulder.

Yates, David N. 1996. WatBal: An Integrated Water Balance Model for Climate Impact Assessment of River Basin Runoff, ***Water Resources Development,*** 12:2, 129-139.