Water Security and Ground Water Problem to Changing Environment in North China

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ABSTRACT

The problems of water shortage, particular in continued over exploitation of ground water in North China, have become the most significant issue to impact sustainable development in this very important region that are political, cultural and economic center of China. This paper addresses these emergent issues by the case study of Haihe River Basin in North China. The new advantage on water international study and background of causing these problems from natural change and particular human activity are analyzed. Key points are addressed as four aspects: (a) the study of the water cycle process impacted by climate change and high intensity human activity, where climate change influence on continue drought in this region was addressed, and human activity was discussed; (b) water utilization related to new economic partner change, such as saving water model; (c) study on eco-hydrology, and interaction of water and ecology impacted by climate change and human activity; (d) reasonable water allocation that including Water Diversion from South to North and saving water issue in local areas. Several suggestions of both study on the water cycle, which is a very important base of water security in North China, and application study of water resources and eco-environmental rehabilitation are proposed. These key issues will benefit to both advantage of water science and sustainable developing in China.

Key words: water security, ground water, environmental change, North China.

WATER ISSUE IN NORTH CHINA

North China is the political, economic and cultural center in China (see Fig 1). In 2000, the population of the North China Plain (NCP) is 437 million, 34.8% of the nation. Moreover, the GDP and irrigable land of the region is 31,300 billion Yuan and 346 million acres, which are 32.3% and 42% of the nation. On the other hand, the NCP is a region having tremendous conflict in the supply and demand of water resources. A water source per capita of Haihe River Basin is only 305 m^3 , that is only 1/7 of the national average and 1/24 of the world average(Chen 1985; Chen, 1994; Chen & Xia, 1999, Wang, 2000).

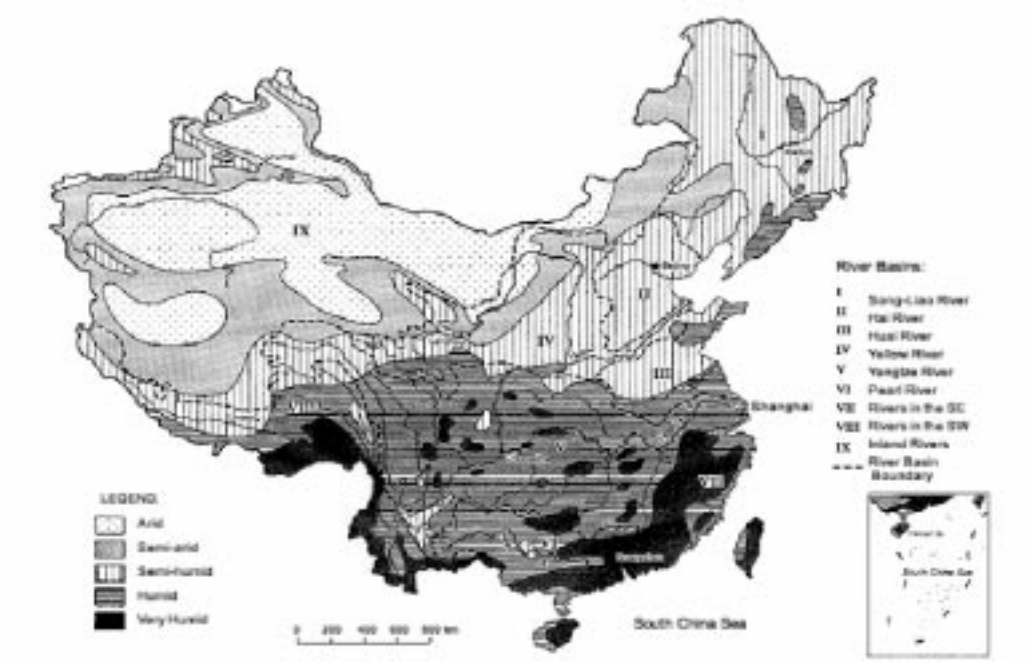

Fig. 1 Major river basins, water resources regions and availability of water resources in China

Due to its natural geographical location, the North China region has suffered frequently droughts. In particular, the severe droughts of 1972, 1999, and 2000 brought along serious water shortage and the nation had to adopt the water supply policy of 'abandon farming, compress industry, and protect living'. From a human geographical perspective, the North China area and particularly the Hai River Basin has a long tradition of heavy human activities and water usage. In the sixties, there were a lot of water resource projects developed to use surface water. In the seventies, especially after the drought of 1972, surface water became insufficient and the exploitation of ground water started. In the nineties, with rapid socio-economic development, the deficiency of water resources lead to the overuse of ground water and rain water. According to international water, a reasonable open up and usage of water resources should be about 40% of existing resources. The usage of water resources in the Hai River Basin, however, is already over 90%. High development and usage of water resources lead to a serious imbalance of supply and demand of water resources in the area. Presently, the runoff of the Hai River Basin is diminishing drastically. The exploitation of underground water is about 90 billion m^3. At present, the annual shortage of water is over 80 billion m^3, which is mainly covered by the utilization of underground water and polluted water (MWR, 1992; Zhang, 1992; Zhang,1995, Wang, 2000; Xia & Chen, 2001).

The lack of water resources not only hinders the development of national economy, and it leads to severe environmental problems in the Northern China region, and especially the Hai River Basin.

Large reduction of water from the mountains, and serious reduction of water resources

Take for example the Mi Yuan and Guan Ting reservoirs, which give the water supply to Beijing, the capital city. During 1955-1984, the annual average of water supply from Guan Ting Reservoir is 1.13 billion m^3; but in 1985-1995, the average annual supply dropped to 270 million m^3, only one quarter of the previous period. The rainfall in both periods, however, is both equal to 407.5mm. The water supply of the Mi Yuan Reservoir is also showing a serious decreasing trend. As compared with the period 1960-1979, the annual water supply in 1980-1997 decreased by 400 million m^3. Water supply originating from the mountains has diminished drastically, and this has brought along immense damage to the socio-economic development and ecological environment of the cities and the middle and lower stream areas (Qian, 2001; Liu, 2001; Wang, 2000).

Exploitation of underground, and dried up in many areas

Right now, the overuse of underground water in the urban districts of North China is very serious, covering an area close to 90,000 km^2. This is about 70% of the Northern China Plain. These overuse districts form two regions. One is composed by Beijing, Shi Jiazhuan, Bao Ding, Xin Tai, Hang Dan, and Tan Shan, a shallow layer underground water funnel locality of area 41,000 km^2, in which 10,000 km^2 of land has its underground water exhausted. The other region centers on Tianjin, Hen Shui, Chuan Zhou, and Lang Fang. It is a deep layer underground funnel locality that covers an area of 56,000km^2. The drying of underground water directly threatens the water safety of the North China Plain, and leads to sinking of land surface and rising sea level, which are dangerous conditions. A scheme of groundwater change in Shijiazhuang city in North China was shown in the Fig.2 (Liu, 2001, Wang, 2000).

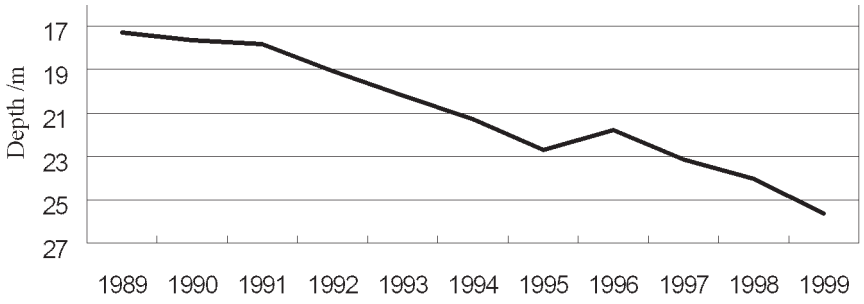

Fig.2. A scheme of groundwater change in Shijiazhuang city in North China

Rivers and Lakes Degradation

Presently many rivers in North China are dried out and broken, lost their function of refilling underground water, and carrying away sand and salt. The ecological problems of land reduction and wetland shrinkage are very serious. According to statistics, in the total length of 10,000 km of river, 4000 km have been dried up. In the Hai River Basin. 1,940,000 acres of lakes and wetland are already waterless. The river flow volume into the sea has dramatically decreased from 24 billion m^3 in the fifties to about 10 billion m^3 in 2001. The ecological system of the Hai River Basin Has transformed from an open mode to an inland and

closed mode, causing the accumulation of sand and salt at the river mouth, the destruction of natural conditions and the extinction of many marine species (Wang, 2000; Xia & Chen, 2001).

Water pollution

In the past 20 years, water pollution has developed from local segment of a river to the whole river, from lower stream to middle and upper stream, from city to village, and from land surface to underground. From statistics, the annual discharge of polluted water into the Hai River region is as high as 6 billion tons. The Guan Ting Reservoir started to stop the supply of fresh water from 1997 because of pollution. In the Hai River Basin, 20 billion m^3 of polluted water are still used annually for irrigation, and this has caused pollution to shallow layer underground water, soil and farm products. (Wang, 2000).

There are many factors bringing along the hydro-ecological change of the North China region, but the key problem is the water issue. Namely, in the interaction between human activities and Nature in North China, there are 'unhealthy' impacts to the water cycle. For example, continued drought in North China naturally brought along insufficient rainwater; changes of land use and cover alter the atmosphere-land surface relationship; urbanization accelerates the utility of deep layer underground water and pollution. Numerous reservoirs and anti-flooding projects in the basin area modifies the natural water cycle and drainage system of the rivers, reduces the function of the mid-lower stream for water recovery and saving. The water use that comes along with socio-economic activities intensifies the facet of water consumption in the water cycle, and the over-exploitation of underground water from human activities greatly diminishes the revival possibility of water resources in the region.

To alleviate the water shortage of North China, people adopt various techniques of management and resource transformation to save water, and increase the local water supply through water diversion across basins. As compared with the natural water cycle, the impact and use of modern water resources science on the 'artificial' water cycle brought along by intense human activities are getting more and more important. As such, pioneering researches on the water cycle of North China in a changing environment, understanding of the 'unhealthy' water cycle and its relation to the water shortage and degradation of hydro-ecological conditions of North China, proposing sustainable strategies that can resolve the water safety problem and improve ecological conditions, are fundamental questions of water science in the 21st century.

ADVANTAGE OF RESEARCH OF WATER PROBLEM

The security of water resources is a hot topic on international & Chinese water resources research. It is not only directly related to the water cycle, it is also related to the basic demand of water resources by human beings and their living environment, the demand of water by ecological environment, the national safety, the value of water, and the problem of the scientific management of water. Therefore, the water cycle and water security research of regions with intense human activities is an important and leading problem in international and national research on environmental resources.

China is big country with much more pressures from its population. Due to serious conflict of economical development and water shortage, Chinese government has been a high concern for the water resources

problem of North China. The project "Water resources assessment in North China " was established in the "Sixth Five Year Plan". In the "Seventh Five Year Plan", and "Eighth Five Year Plan", the projects "Water resources research on the North China and the Shanxi energy base", and " Treatment of Yellow River and water resources research" were implemented respectively. In the "Ninth Five Year Plan", two key projects, namely "The reasonable extension and use of water resources in the Northwestern Region and the protection of its ecological environment" and " Research on the exploration and use of water resources in the mid-lower stream of Yellow River and the technologies for clearing river blockage" were introduced to synthesize the exploration and use of water resources in a region and its economic and ecological protection. National Fundamental Scientific Research Project has also implemented with the topic of " The evolution of water resources of Yellow River and its renew-ability" (Liu, 2001).

The Chinese Academy of Sciences (CAS) supported a series of research projects related to water issue in North China. Based on hydro-ecological experimental stations and their network, such as the Yuchen Agricultural Experimental Station and the Luanchen Experimental Station model, we have continually built up the North China eco-agricultural water resources experimental site. During the "Ninth Five Year Plan", we embarked on one of the key projects of CAS, "Changes and allocation of water resources in North China". In 2001, the research project " Water Cycle and Water Security of North China" was supported by the "Knowledge Innovation Projects" of CAS (Xia, 2002).

In the proposal of the "Tenth Five Plan" in China, it emphasizes water issue and reasonable utilization in the development of national economy. To reduce water shortage problem of North China, it is pointed out the need to speed up the preparatory work for the "Water Diversion from South to North" project, to set up appropriately other cross-basin water diversion projects, and to adopt a multi-dimensional approach in easing the problem of water shortage of North China. At the same time, it emphasizes the problems: " Highly regard the sustainable use of water", " Fortify the construction of appropriate ecological conditions" and " Protect and care for the environment". The Premier Zhu Rongji stresses that we must properly understand the relationship between the "water diversion from south to north" project and the treatment of polluted water, saving water, and the protection of the ecological environment. We have to achieve the "Three first three next" principle, i.e., " Save water first and divert water next", "Treat polluted water first and next supplied water", and " Consider environmental protection first and next use water".

In the beginning of 2001, the Ministry of Sciences & Technology jointed with Ministry of Water Resources proposed the project " Research on the Key Techniques of the Security System of Water Safety". Here vital techniques involve use of seawater, ways of using polluted water, ways of using flooding water (adjustment by reservoirs), and techniques of human rain production.

In all, from the trend of development, it is a frontier problem in international water sciences to understand water cycle and water resources security to changing environment. It is also is a new fundamental problem of science that comes along with the demand of water resources due to the socio-economic development activities of mankind.

GROUND WATER PROBLEM IN NORTH CHINA

Since a great deal of water has exploited for rapid development of industry with the urbanization supply of water resources for the agriculture has declined. Rapid development of cities and industries and extensions in farmland irrigation has doubled water demand. The consequence is overuse of surface water resources and excessive exploitation of groundwater in the areas.

In vast area of the North China plain, the buried groundwater table declined from a depth of 3 to 4 meters in the 1950s to more than 20 meters in 1980s and about 30 meters in 1990s that showed the g.t. declining with accelerating rate. Declination of the groundwater table observed along Jing-Guang Railway line in the region of North China were shown in the Figure 3. In such a case, the excessive exploitation of groundwater persists at this rate, the obvious result would be a sharp rise in the irrigation cost along with a water resources crisis in the near future. When the irrigation water supply cannot be assured, high-output agriculture in the plains is not sustainable. A degradation of groundwater quantity and quality would take place in wide areas. Located at the lower section of the Plain, the Heilonggang River basin being of low-lying flat lands has suffered from shortage of surface water. People have extensively carried out mining of limited groundwater from deeply buried aquifers, although lower output, there, obtained. Deep wells in the areas were sunk to pump deep groundwater since the beginning of the 1970s. The result was a persistently high rate of excessive withdrawing, leading to a deep groundwater table decline of 2 to 3 meters per year and to the formation of large depression cones in a wide extent. From the 1980s, exploitation of the shallow aquifers has also occurred. Although the area of farmland under irrigation increased and output rose apparently, the elevation of groundwater table generally declined below the sea water level about 80 meters found in Chaozhou Prefecture of Hebei Province. As a result, groundwater has been over-pumped seriously in both rural and urban regions, the lowing down of groundwater table greatly to cause severe impacts on both the groundwater itself and the environment. Firstly, the quality and quantity of groundwater water have gone worse. Secondly these result in the problems of land subsidence in a number of places and seawater intrusions in coastal plains along the Bohai Gulf. It is very serious that in wide part of the Heilonggang in the Hebei Province deep groundwater has a content of fluorine and more than one million people are drinking the high fluorine water that is very harmful to hearth of local people. In addition, due to pollution, groundwater in some places contains certain bacterium, and many residents have to drink organic-polluted water and high-nitrate water.

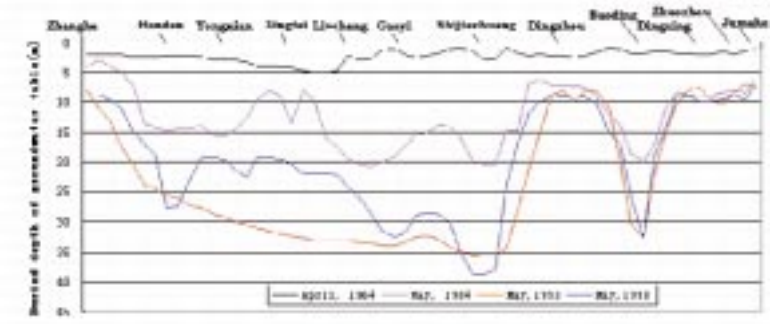

Fig. 3. Declination of the groundwater table observed along Jing-Guang line in the region of North China

To understand impact of climate change, and particular human activity to ground water, regional change and analysis in large scale are required. New tools, such as isotope hydrology & integrated groundwater & surface water modeling, are applied widely to North China Plain. Several scientific research problems were addressed. One of then is the estimating groundwater levels within a large-scale domain

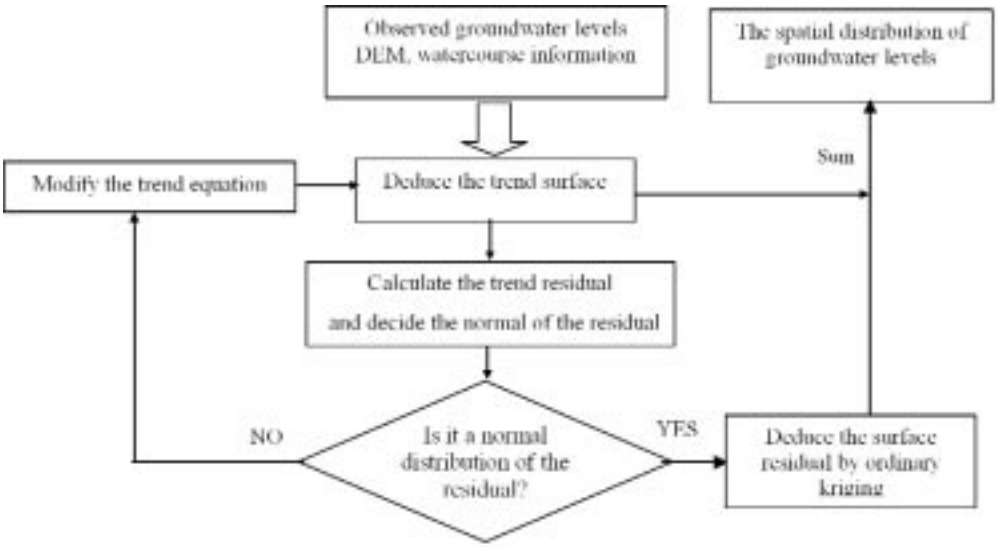

Figure 4 (a) . Flow chart of DEM-RK model

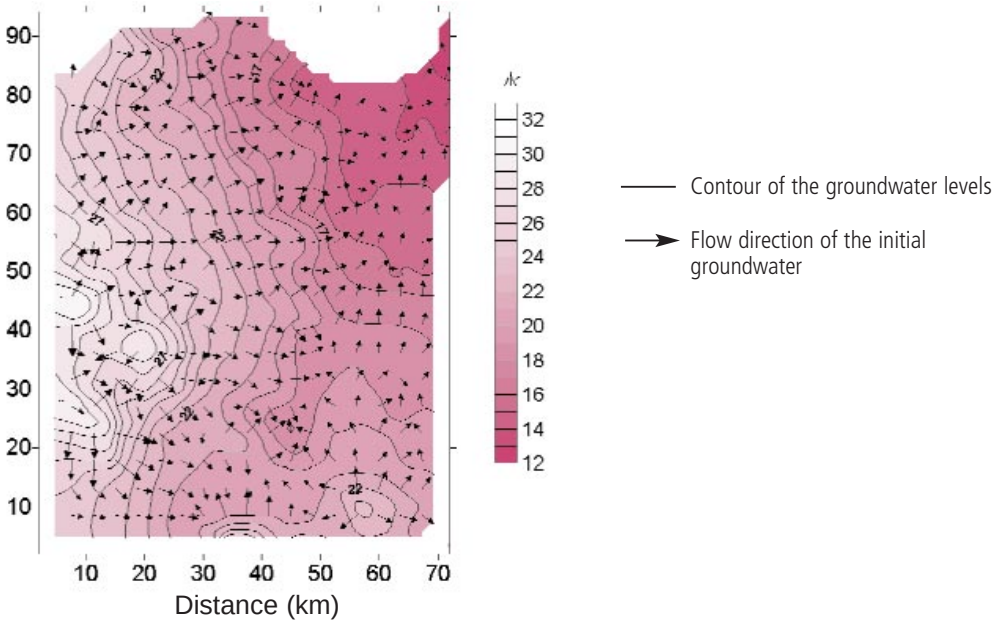

Figure 4(b). The estimated result of the initial

For instance, understanding the movement and change of groundwater is a basis of the effective groundwater resources management, wherein the information about spatial distribution of groundwater levels is indispensable. Geostatistical methods like kriging has been widely used to estimate groundwater levels based on observation wells. The errors are inevitably introduced through the interpolation process so that how to increase the accuracy and accuracy based on limited well data has become an urgent issue for estimating groundwater levels, especially for a large area. This study developed an integrated DEM-based residual kriging (DEM-RK) model for estimating groundwater levels within a large-scale domain. The model can yield more physically plausible estimates of groundwater levels in a large-scale domain than those currently in use by effectively utilizing well data and considering the influences of terrain morphology on the groundwater flow. The model was then applied to the Fuyang River Basin, a 5000 km^2 study area, in the North China for estimating the regional groundwater levels and flow. The Kolmogorov-Smirnov (K-S) test was employed to prove that the DEM information could markedly facilitate the residuals to approach a normal distribution, which ensures a satisfied estimate accuracy. For demonstrating the advantages of the proposed DEM-based trend surface, three types of trend surface using both simple and quadratic equations were developed to estimate groundwater levels. Based on the verification points, the average error (ME), the average absolute error (MAE), and the square root of the quadratic multiply error (RSME), for each trend surface equation were compared. The DEM-based trend surface equations were discovered with the highest accuracy. The results indicated that quadratic equation could more effectively present the trend surface than simple one with a higher correlation coefficient. However, for a large-scale estimation domain with limited well data, the simple equation for DEM-based trend surface showed more feasible with a better accuracy than the quadratic one. Further research on improving trend surface simulation to more effectively reflect system complexities would be desired.

NEWLY PONDERING TO WATER ISSUE IN NORTH CHINA

Despite some effort and research have been spent on water resources in North China, water shortage in the region remains a serious problem. The water eco-environment has become more and more critical. In addition to socio-economic development, population growth and environmental evolution in the region, there has been a lack of key, basic and scientific research on the inter-effect of water cycle and eco-environment (Xia 2002). In order to alleviate the water shortage and eco-environmental deterioration there is therefore a need for urgent and extensive research. The current key problems in water resources in Northern China that need urgently resolved include:

Causes of decreased water input from mountainous areas in Northern China

Over the last thirty years, both the water resource and water output from the Northern mountain areas have substantially decreased. There are a lot of questions that are yet unanswered: What have caused the water resources shortage, the weather? human activities? How are the water consumption behaviors attributable to human activities? What influence has land usage and it changes in the mountain areas on the water cycle of the drainage areas? A lot of water work and water preservation work have been built in the mountain areas since. What role have these works played in the process of water resource reduction? How can their functions be identified and what are the relations of these functions to water resources protection in the source region? So far very limited research has been dealt with these many issues.

Water cycle and underground big water funnel problems in urbanized areas

There has been extremely weak research that investigates the urbanizing water cycle primarily characterized by human activities. The seriously lagged behind socio-economic development in the urban areas has led to urbanized eco-environment problems brought about by concentrated water supply, water pollution and underground big water funnel effect. The phenomenon of underground big funnel is mainly found in urban areas in Northern China. This is largely attributable to nonstop over extraction of water resources. Evidently, underground waters at shallow level and at deep level possess very different ability to recover. There are several urgent issues that needed immediate research and solutions. How have the water resources at both shallow and deep levels been changing? What are the relations of concentrated and supplementary water supply in urban areas to the groundwater resources and their qualities in shallow and deep levels? What are the relations of shallow level groundwater resource and quality to those of the deep level? How can underground water funnels be recovered? How can underground water pollution be avoided?

Mechanism of "groundwater-underground water" under deep layer in agricultural plain

The function of groundwater resources under the deep layer in the agricultural plain today is more important in comparison to the Eighties. However, investigation on the mechanism of "groundwater-underground water" under the deep layer and on the change of underground water parameters is very limited. This has adverse effect on the fundamental problem of water savings in farming and the evaluation of water resources.

Limited knowledge of the evolution of water eco-environment in the Northern region

There has not yet a consensus on few important water issues in this area. What are the influences of human activities, including large-scale water plants in the Haihe drainage region, on the deteriorating process of the Northern eco-environment due to sustainable drought in the region? How can conflict and convergence between flooding, drought and eco-environment preservation reconciled?

Living-production-ecological consumption of water

The mayor water issue that we are facing is lack of research on water needs, in particular the ecological need of water, in the region that is in a process of socio-economic transition. In addition, there are several key questions to be answered. What are the structure and the apportion of living-production-ecological water consumption that will fit in the present conditions of Northern China? What will the anticipated changes in living-production-ecological water consumption be in the process of socio-economic transition of the region? How can future water consumption in living-production-ecology, particularly in ecology, be predicted?

Parameters controlling changes of eco-environment and ecological recovery target – untouched areas

It is a well-known fact that water shortage and its induced deteriorating ecological environment has been persisting in Northern China. In order to sustain the continuing socio-economic development on one hand

and to preserve the ecological landscape on the other, of the region, there is a lot of work to be done. These include the solution of a set of parameters that control the recovering of underground water, avoidance of sinking ground level, prevention of seawater polluting underground water, the target recovery level of ecology and regulating water need to retain drainage ecology. Unfortunately, not any work on the above problems has been started yet.

Drainage water cycle and water collection system

In connection to the influence of human activities on drainage water cycle, Chen (1986) was the pioneer who proposed the idea of "manmade side water cycle". Later, Wang H (???) suggested the idea of a bivariate "nature-manmade" water cycle model. No research output on these issues has emerged so far. In solving regional water shortages and in eco-environment recovery, we are still in need of a simulation system that is capable of simulating the changes in the water cycle and evolution of the eco-environment.

Transportation of Southern water to the North

There is a need to strengthen the scientific research on how to allocate among surface water, groundwater and imported water when the South water to supply the North project is in force. The water supply is then comprised from surface water, underground water, imported water and regenerated water within the supply district. An urgent research topic is how to allocate the various supply sources and to optimize the overall efficiency of these water sources, given the limited surface water storage capacity. One critical issue is to determine the allocation strategy and criterion that are scientifically sound, to solve the water shortage problem and to recover the eco-environment of the Northern region. Critical socio-economic issues will also emerge. This involves the amalgamation of natural and social issues in a harmonic manner to formulate and support decisive policies for the continuing socio-economic development and adjustment to the future socio-economic structure of the region.

RESEARCH PROBLEMS AND NEW CHALLENGES

Based on the national demands on water cycle research, there are several crucial challenges related to the water resource safety in Northern China:

Quantification and validation of human influence on water cycle and eco-environment

Northern China is a densely populated and economically well-developed region. The conditions based that river runoff is produced and underground water is recovered have undergone noticeable changes since the early Eighties. These have added difficulties in the evaluation of solution methodology to solve water problems in the area, such as the noticeable reduction of runoff from the catchments area, deterioration of the big underground water funnel phenomenon in the urbanized area, and district-wise water resources estimation. What are the causes for such changes? How can the contributions of manmade side water cycle system be identified and evaluated? Can contributions of human activities to the eco-environment be quantified? Last but not least is the key to uncover the causes for the continuing deterioration of the econ-environment within the Haihe drainage is to conduct a thorough analysis on the evolution process of its eco-environment in the last fifty years.

Water consumption pattern during socio-economic transition

Because of the dilemma existent between the specificity of its location and water resources restraints the composition of water consumption in the Northern region has been ever changing. The economic infrastructure is facing restructuring and challenges from preferred production development model upon globalization. A crucial scientific issue is to predict the changing pattern of "living-production-ecology" water consumption, especially the prediction of water consumption for ecological purposes. Obviously, experiences of developed and developing countries should be very useful. Any meaningful research on the topic will inevitably involve the integration as well as inter-referencing the fields of economics, geography, ecology and water resources.

Mechanism of changes in drainage water cycle and eco-environment

The ever deterioration of eco-environment is one of major causes of water shortage in the Northern region. The issue is related to geography, hydrology and socio-economics. Several questions may be posed in this respect. What is the concrete relation between the changing process of the drainage water cycle that is attributed by intensive human activities and the changing process of the water eco-environment? How can a model be formulated to describe the influence of intensive human activities to the drainage hydrology-ecology? Repeated simulation of such a model so that quantified changes in hydrology-ecology can be evaluated should be able to throw some light on the solution methodology of the problems.

Efficiency allocation between "water saving-water reallocation-water consumption"

There has not yet an agreed principle based on which the allocation efficiency of various water sources can be evaluated. When the South water is transported to the North, a rational principle to allocate various water sources efficiently is yet to be derived. Many questions remain unanswered. What is the position of the future economic system within the context of ecological system as a whole? How can the conflict between water consumption for socio-economic activities and for eco-environmental recovery be eliminated, given the condition of limited water resources? How can the efficiency in agricultural water consumption be improved through a structuring of the giant agricultural economic systems in the region? There are basically four key areas of concerns, namely drainage water cycle, ecology evolution, water consumption for socio-economic activities and the system formed by them. To fulfill the national requirements it is suggested to investigate the efficient allocation of future "water saving-water reallocation-water consumption" that would meet the criterion of sustainable development.

CONCLUSION REMARKET

There has always an unavoidable conflict between the intensive human activities / social-economic development and eco-environment. This conflict become ever markedly in the last fifty years. Can this conflict be eliminated? A basis that formed upon the principle of sustainable development from a macro-strategic perspective should hint the solution methodology to alleviate the conflict. A sustainable development model built upon eco-economic values would suggest a plausible economic development model for Northern China that is beneficial to its own environment. To work out effective solutions to

recover the eco-environment of the region and hence to solve the water shortages it is a vital recognition that we not only need innovative ideas but also sufficient fundamental research on the ever-serious water crisis both within the regional context and the national context at large.

In the coming ten years, research achievements will be on water cycle, eco-environmental changes, water consumption for socio-economic activities, recovery and control policies and integrated model simulation can be realized.

Focused research founded on water cycle level in Northern China:

(1) Weather background of the drought and ecological evolution.
(2) Mechanism of water cycle under the influences of typical runoff changes in mountainous areas and in environment.
(3) Water environment changes and underground water renewability in typical urbanized areas.
(4) Mechanism of environmental changes and water cycle in cultivated plain.
(5) Water cycle in the basin and its distributional model in the changing environment.

Focused research founded on evolution of water eco-environment and soc-economic consumption of water:

(1) Formation and evolution process of the contemporaneous framework of eco-environment.
(2) Water consumption pattern under socio-economic transition, safety level of eco-environment and its recovery target.

Focused research on water diversion and water savings problems in the North founded upon water resources safety and eco-environment recovery policy:

(1) Water-ecology-socio-economic integration framework.
(2) Policy to solve water shortages and ecology recovery.

Thus, the following are urgent and prominent issues: water supply in urban areas, typically in Beijing area and sustainable water resources problem; water saving potential of the large water resources consumption agricultural units; and the adjustment of the production structure in Northern region. When research is directed to the theoretical basis and applications of eco-environmental water resources progress and breakthrough will be expected emerge.

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