On Evolutionary Laws & the Maintaining Mechanism of Reusability of the Yellow River Water Resources

Changming Liu
United Research Center for Water Problems
CAS, China

1. Research contents & significance

1.1. Background

The Yellow River has a vast valley area and historically it is the mother river of the Chinese nation. Now it serves as one of the main theatres for the on-going national campaign to develop China's western hinterland. As the majority of the landmass covered by the Yellow River Valley is dominated by semi-arid climate, the Valley's water resources are congenitally deficient as its water occupancy per capita is less than 1/3 of the national average. What is worse, frequent dried-ups in the lower reaches of the Yellow River mainstream occurred in the latest 30 years. The ominous development not only aggravates the fragile balance of the water supply in river basin areas, but also brings in new impacts on the native eco-system along the River's reaches. Historically, the River's harnessing used to be a state affair of vital importance for the national stability. Since the founding of the People's Republic in 1949, the country has achieved enormous success in this aspect. Yet, due to the predatory exploitation of the water resources and changes in natural conditions, the Yellow River is to face a serious and grim plight interwoven by intensified shortage of water resources, a higher and higher frequency of water-related calamities and the worsening situation of its eco-systems. This is the resultant consequence from the vicious development of the interaction between the River water-soil-ecosystem and the socio-economic system of man in the Valley. The shortage of water resources is the crux of the three curses now plaguing the River Valley. The formation, evolution and renewable capacity have their own self-governing laws. But the intensified human activities have infringed the original circulation of natural water and brought in remarkable changes to it, triggering acute tension in the normal supply of water resources in the Valley. As a result, a series of degenerative processes come into being in the environment and ecological balance. This is the main cause leading to the emergence of the three curses and becomes the bottleneck for sustainable development in the Yellow River valley. So the study on the evolutionary laws and the mechanism to maintain the renewable capacity of the water resources in the Yellow River basin becomes the critical factor and the strategic requirement of the whole nation in harnessing the muddy water of the River and introducing a sustainable development to the river basin areas.

1.2 Thinking approaches for the research project

The overall thinking approach is to give a precise and in-depth analysis of the formative factors of the water crisis in the Valley. By screening many S&T issues cropping out from the crisis, some key problems with fundamental significance are to be pinpointed. Based on the formative and evolutionary laws of the River water resources, new questions on renewable utilization and its maintenance are explored. Theoretically aligned by the water circulation and renewable capacity, a duality model on water resources is to be developed. Furthermore, under the theoretical guidance of the maintenance of renewable capacity and multi-dimensional and synthetic modulation of several critical values, the sustainable utilization of the water resources might be realized. In the same time, the changing mechanism of a water-and-silt process, the river flow withering mechanism and the formative mechanism which enables small floods to cause destructive calamity are to be deeply revealed. A series of workable measures for rehabilitating the Valley's depleted ecosystem and a waterway capacity to accommodate a flood has to be developed. In this way, a sound theoretical groundwork might provide for alleviating the water crisis, saving the ecosystem from further deterioration and control of the flooding calamities in the Valley.

Based on the above thinking approach, eight research topics are instituted, including dynamic mechanism and model of the Valley's water circulation, the evolutionary law and duality evolutionary model for the water resources, the fluvial functions and the transformation structure of the water resources in the River's lower reaches, the theory of renewable capacity of the River water resources and its evaluation, the change in the renewable capacity of the Valley's underground water, the feasible approaches for keeping the water resources renewable capacity and the multi-dimensional model for critical regulation. In combining the digital Yellow River tasks set for a project spearheaded by the Yellow River Water Conservancy Committee, methodologically, the project features both multi-disciplinary synthesis and inter-disciplinary hybridization. It borrows methods from earth sciences such as those from hydrology, science of water resources and geology / geomorphology, fluvial dynamics and systematic analysis and macroscopic decision-making from systems science and economics, as well as appraising analysis used in disaster reduction and environmental science. In the combination of the surveying data with simulation tests in labs, the project conducts the mathematical modeling based on the introduction of RS, GIS and GPS technologies. Through the marriage between analytic probes into micro-mechanical mechanism and macroscopic laws in regional geography, the assortment and integration of hydrological models to depict a unitary watershed or the whole Valley are to be realized.

2. Major Research advances so far having achieved

2.1 Phased advances in theory and methodology

1. In dynamic simulation of a water circulation, the project's tests have obtained results from

hundreds of runoff process experiments, developing a distributive hydrological model based on continuous and motive equations;

2. A theoretical model to depict the duality evolutionary laws of water resources in arid and semi-arid areas is constructed and via an analytic study on the characteristics of chaotic dynamics in the Yellow River's annual run-off volume at 100 year scale, a related quantitative model for defining the River's historical evolution was initially established;

3. Based on continuous real-time remote-sensing materials provided by NOAA/AVHRR during the period from 1981 to 1999, the changes in the spatial distribution and temporal dynamics of the Valley's annual evapotranspiration during the period are estimated successfully;

4. A group of preliminary results on the mechanisms governing the River's flood-accommodating capacity in its lower reaches and comprehensive influence on the fluvial functions when dried-ups of courses occur are obtained;

5. By employing the theory on the balancing the silt in the Valley, the influence of measures set for water-and-soil conservation on the Valley's silt transport ratio was probed;

6. A theoretical framework on the renewable capacity of the Valley's water resources volume was initially developed;

7. The concept and its types of the least water quantity for an ecosystem were defined and related computational methods were developed;

8. The first attempt in the country to classify the underground water systems in the Valley, solving the poser of numerical simulation on the movement of multi-layered groundwater aquifers and flows which contain water-saturated and unsaturated zones.

9. The refreshment, runoff and discharge of the groundwater in the Valley by using stable isotopes (^{2}H, ^{18}O and ^{13}C) and radioactive isotopes (^{3}H and ^{14}C) are achieved successfully.

2.2 Main staged advances in the project's applied basic research

1). The critical riverbed's specific drop in a silt-reducing ditch dug at the suspended river in the Yellow River's lower reaches is suggested, the feedback influence of the River estuary's evolution on tailing channels and the silt-carrying capacity of the suspended substance driven by the tide and waves at the River mouth are expounded, providing scientific grounds for harnessing the river channels in the River's lower reaches;

2). The least water volume needed for sediment transport from the River's lower reaches for the coming 20 years since the Xiaolangdi Reservoir has started its operation is estimated for prediction.

3). The relationship between the natural degradation of hydrocarbon pollutants in the water body of the Yellow River and rehabilitation of the contaminated water are revealed.

4). Via making clear the formative law of sloping gradients on the land forms of the Loess Plateau, the project works out scientific measures for recovering farmlands to forest- or grass-covered wilderness;

5). A system of parameters has been erected for evaluating the renewable capacity of the water resources in the Valley and the capacity was then evaluated in line with the new approach

6). The new thought "critical control" is first applied to the unified management and deployment of the water resources;

7). A study on the water quantity regulation model for the low-water season in the lower reaches of the Yellow River and the new model has been applied to the allocation and deployment of water resources in the Valley.

2.3 The establishment of related technical support systems

The project's achievements in this aspect include the elementary data base for the water circulation in the Valley, a databank for the socio-economic materials in the middle and lower reaches of the Yellow River, a databank for evaluating the renewable capacity of water resources in the Valley, a databank for the historical materials of water-and-soil conservation and land-use, the former including observational and on-the-spot surveying data obtained from more than 400 areas in 13 geographical zones while the latter containing 6,188 entries of information collected from 221 counties of Shaanxi, Shanxi, Gansu provinces, Ningxia Hui and Inner Mongolian autonomous regions. In line with the technical norms decreed by the information center under the Ministry of Land & Resources in 2,000, the groundwater databank was erected for the Yellow River Valley. Based on GIS, a management system on the basic databanks on the areas irrigated by Yellow River water in the River's lower reaches, capable of carrying out digital editing, searching and visual display and bringing in a platform for materials and data was established for the Valley's infrastructure.

3. Chief scientist in charge of the research project

Prof. Liu Changming, CAS member and director of the Joint Research Center on Water Problems under the CAS, Director of the Shijiazhuang Institute of Agricultural Modernization, Dean of the College of Resources & the Environment, the Beijing Normal University and Vice president of Geographical Society of China(GSC).

He had served as Chairman of the Hydrological Committee, GSC, Vice Chairman of the Forest Hydrology and Watershed Management, China Forestry Society, Vice President of the national committee under the International Association of Hydrological Science, Chairperson of the Study Group"Regional Hydrological Response to Global Change" under the International Geography Union (IGU), Chairman of China's national committee for IGBP/BAHC, member of scientific steering committee of IGBP/BAHC, Vice President of the IGU from 2,000 to 2004. Also, he now serves as an editorial member of both *Hydrological Processes* and the *International Journal of Water Resources Development* as well as editor-in-chief of China's *Acta Geogrpahica Sinica and Journal of Geo-Agricultur.*

Main achievements:

1. Prof. Liu has devoted his personal career to hydrology and water resources, one of the hot issues of today world's concern, by linking engineering sciences with earth sciences and thus forming the theoretical and methodological foundation for China's geographic hydrology and water resources research. In addition, he succeeds in developing research and teaching bases, a contingent

of talents in the CAS and Beijing Normal University such as the inauguration of a Joint Research Center of Water Problems, CAS and an Institute of Water Science and a key lab in Beijing Normal University.

2. In the surveying design of a railroad, he develops a model for computing the small watershed peak flows caused by the rainstorms so that the poser had been solved for the ungauged catchments. The formula was applied to the design of eight railroads including the Qinghai-Tibet Railway and the Line No. 101 in Xinjiang in Northwest China.

3. In the National Project of South-to-north Water Transfers, he suggested an analytic method for water diversion in a system of geographical hydrology, promoting the application of the theoretical methods on regional water and heat balance to water distribution and appraisal of the influence on the environment in the project.

4. In coping with the problem of farming irrigation, he developed a systematic theory on water-saving agriculture, enriching its disciplinary contents, and suggested a numbers of new ideas in this field.

5. He participated in the CAS-sponsored consultant projects under the titles of "On the way out for problem of China's water shortage" and "Countermeasures for alleviating the dried-ups in the Yellow River mainstream" and worked as partner of consultant projects sponsored by the CAE such as "A Strategic Study on Water Resources in China's Sustainable Development" and "A Study on Water Resources in Northwest China and Protection of the Eco-environment and Sustainable Development."

6. He hosted a research project under the title of "Water-saving Demonstration in Farming Undertakings & Sustainable Utilization of the Groundwater in Typical Hebei Plain Areas" a key R&D project initiated by the S&T Department of Hebei Province.

7. He so far has groomed more than 60 postdoc-graduates, has more than 200 monographs and research papers to his credit and won 12 prizes granted to him by national, provincial and ministerial authorities.