Study on the Eco-Environmental Control Models of Small Basin in Arid Land, Western China

Zuo Qiting and ***Ma Junxia***

College of Environmental & Hydraulic, Zhengzhou University, Zhengzhou 450002, China
E-mail: zuoqiting@263.net and zuoqt@zzu.edu.cn

Abstract: Adopting optimum control and scientific management for eco-environment is very important to protecting eco-environment against disruption and promoting the coordinated growth of soc-economic system and eco-environmental system and building a harmonious relationship between human behavior and natural world, especially in the arid land, western China. This paper, according to the eco-environmental characteristics of small basin in arid land, from the point of overall development of small basin, introduces the theory framework of eco-environmental control, and puts forward two main types of control models, that is, Dispose-Water-Model and Coordinate-Model. In the paper, a case study will be introduced too.

The paper provides several good models and examples for eco-environmental control of small basin in arid land.

Keywords: arid land, small basin, eco-environmental control, model

1 Introduction

Eco-environmental systems are dynamic, changing units, including biogenic and nonbiogenic ecological factors. These factors, including man-made factors and natural geographical condition such as grass and plant vegetation, river and lake, soil and climate, influence the changes of eco-environmental systems. These factors also are environmental basic of human existence and human behavior and social development. But how to coordinate the relationship between human behavior and natural world will be a key problem and challenge.

Especially in arid land, a lack of water is the primary factor that determines that an area's eco-environment will be very fragile. How to build eco-environmental control model systems to guide us forward to control an arid land's eco-environment will be very useful and important.

The factors that influence eco-environmental evolution can be divided into two aspects: natural and man-made factors. So scientific eco-environmental control should start with two above aspects and build a harmonious relationship between human behavior and natural world. This paper, according to the eco-environmental characteristics of small basin in arid land, taking Bosteng Lake basin in Xinjiang, China as an example, from the point of overall development of small basin, introduces the theory framework of eco-environmental control, and puts forward two main types of control models, that is, Dispose-Water-Model and Coordinate-Model.

2 Eco-environment structure characteristics of small basin in arid land

Ecosystems structure of small basin in arid land and its hydrological cycle and other main characteristics can be summarized as Fig.1. These characteristics are common grounds of numerous basins in arid land. Natural geographical position and man-made remake function and water resources formation and transformation together determine different position's industrial structure and characteristics in a small basin. For example, in mountainous region ecosystem, water resources is plentiful, but climate is unique and suitable for forestry and grass living, so forestry and animal husbandry are its main industries. However, in artificial oasis distribution area, water resources change and consume are very strong, and industry and agriculture are main types. In lowest region of a basin, natural wetland, lake, and natural oasis are usually formed and appeared. It is main area of runoff drainage, gather and transpiration. It is also main distribution area of fishery, tourist trade in arid land. On the other hand, its

ecosystem is man-made, and the area is artificial oasis. It also is one of main industrial and agricultural distribution areas in arid land. Approach to desert, semi-natural ecosystems change into natural desert ecosystem step by step. In desert, production ability doesn't exist at all or is very low.

Ecosystems types	Natural ecosystem Mountain ecosystem	Man-made ecosystem Artificial oasis	Natural ecosystem Natural oasis and wetland	Man-made ecosystem Artificial oasis	Semi-natural ecosystems Natural oasis and transition area	Natural ecosystem Desert ecosystem
Water resources formation and change	Runoff formation, Plentiful water resources	Water resources change and consume	Runoff drainage, gather and transpiration	Water consume area of artificial draw water	Drainage and transpiration area of groundwater	No water or water shortage
Main industrial structure	Forestry and animal husbandry	Industry and agriculture	Fishery and tourist trade	Industry and agriculture	Animal husbandry	No or little production ability
Control ways	To harness the mountainous areas for conserving water and maintaining water sources	To utilize water resources rationally, and to construct the artificial oasis for improving the living and development environment	To assure ecological demand for water resources, and to protect wetland	To utilize water resources rationally, and to construct the artificial oasis for sustainable development	To assure ecological demand for water resources, and to protect the natural vegetation, and to control land desertification	

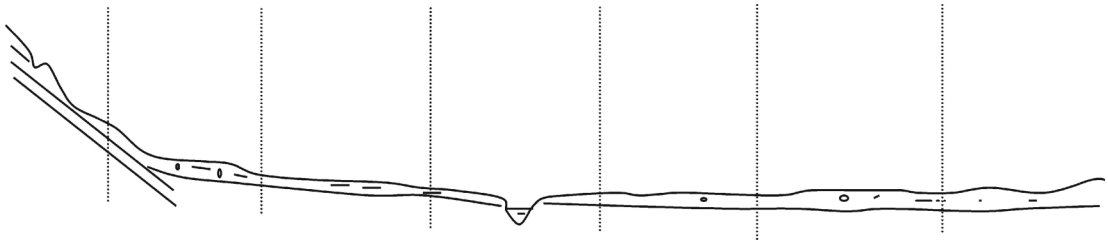

Fig.1 Eco-environment structure characteristics types of small basin in arid land

3 The theory formwork of eco-environmental control of small basin in arid land

Today, with about 6 billion people on the earth, nearly all of the surface of the earth has been affected in some way by human activity. Eco-environment system change is related with human activity. So, when we make eco-environmental control decision, not only aim at eco-environmental system itself, but also aim at social and economic development. It is the thinking theory base of studying eco-environmental control decision making in the paper.

In order to quantitatively express the degree of comprehensive development, the authors have put forward a set of quantitative study method. (ZUO, *et al*., 1999, 2001). The main idea are introduced as follows:

(1) According to index systems and basic criteria and method of eco-environmental quality assessment, we can give quantitative degrees LI of eco-environmental quality. $LI \in [0,1]$, it is called eco-environmental quality indicator, which is a "ruler" to measure the degree of eco-environmental quality.

(2) In the same way, the measurement of social development and economic growth is quantified by an indicator, $EG \in [0,1]$, that gives basic information about rate and quality of regional social development and economic growth.

(3) A hybrid index of reasonable development, $DD \in [0,1]$, is given as a comprehensive indicator integrated from the eco-environmental quality to economic growth, given by:

$$DD = EG^{\beta_1} \cdot LI^{\beta_2}$$

Where β_1, β_2 , respectively, are exponential weights of EG and LI .

DD is a comprehensive "ruler" to measure the degree of development including eco-environmental quality and economic growth.

(4) Build a management model of eco-environmental control facing sustainable development.

Objective function is the maximum value of all comprehensive indicators DD , that is $\max(DD)$.

Constraints should at least include "lowest level constraint of social development and economic growth", and "lowest quality constraint of eco-environment", and "relationship constraint between eco-environment and soc-economy", and other constraints.

Let EG_0 be the lowest level of social development and economic growth, and LI_0 be the lowest quality claim of eco-environment, and $SubMod(EE-SE)$ be the coupling system model of eco-environmental system and soc-economic system. Then general formula of optimum model can be expressed as follows:

$$\left.\begin{array}{c} \text{Objective function:} \quad \max(DD) \\ \text{s.t.} \qquad EG \geqslant EG_0 \\ LI \geqslant LI_0 \\ SubMod(EE-SE) \\ \text{Other constraints} \end{array}\right\}$$

(5) Optimum seeking and making of eco-environmental control plan.

We usually adopt simulated computer technology to obtain approximate optimum answer. Then get practical method to control eco-environment. Its contents include: social development scale, and economic growth rate, and resources usage plan, and eco-environment protection.

This paper only list principal study process, and hasn't more explains. For details, please see the references [1],[2],[4],[7].

4 Case study: bosteng lake basin in Xinjiang, China

The Bosteng Lake is located in the southern part of Xinjiang in the arid and semi-arid region of China. Regionalism of the Bosteng Lake basin belongs to the Banyangol Mongolian Autonomous that is also called as the Bazhou. The Bazhou is the largest prefecture in China, with an area about 480,000 km^2. It has a vast and mysterious land with special natural scenery and fruitful resources on the oil, natural gas, cotton and stock raising etc.

The Bosteng Lake is consists of the Big Lake and the Small Lake (See Fig.2). Even thought annually precipitation amount in this region is only 71mm, the volume capacity of water resources in the Lake reaches 8 billion m^3. The area of Bosteng Lake is about 980 km^2 in normal water stage. Thus, the Bosteng Lake is the biggest inland fresh water lake in the inland region of China. As there is large area of wetland and reed community in the Small Lake region, the Bosteng Lake forms a variety of natural eco-systems including plankton, lake fish and reed source etc.

The main inflow of the Bosteng Lake is the Kaidu river that is the second largest river in southern Xinjiang with the total length 560 km. The water resources of Kaidu river comes from snowmelt runoff from Tianshan mountain. The Kaidu river is divided into east brunch and west brunch at Bolangsumu Diversion structure. The east brunch drains into the Big Lake, and the west into the Small Lake. The Kongque river starts from the Bosteng Lake, drained into the Tarimu river that is the biggest inland basin with the total length 942 km in China.

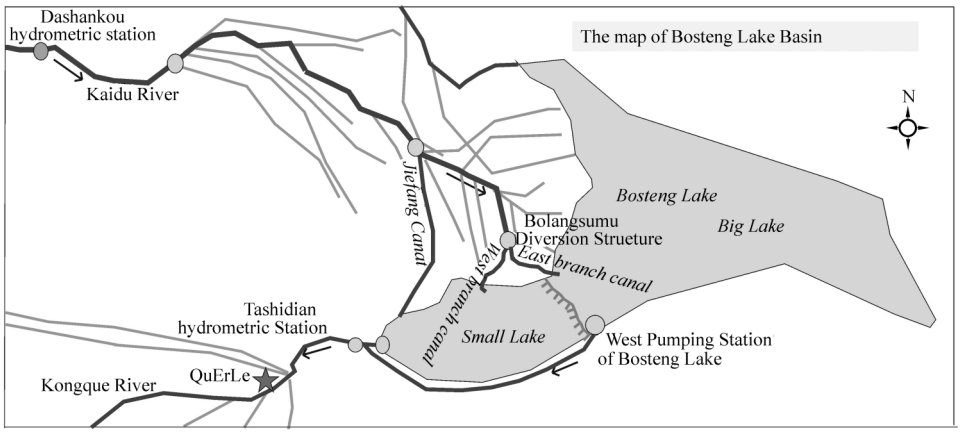

Fig.2 The Bosteng Lake basin

Thus, water resource of Bosteng Lake is quite valuable in the arid and semi-arid region of Xinjiang, China. Because increasing water demand on irrigation, industrialization, and population growth, the Bosteng Lake plays a very important role to support social-economic development in the whole basin. The main functions of the lake have water resources control, irrigation, and ecology and environment protection.

However, there are still many problems and challenges for such a big lake management on water resources utilization and allocation to trade off contradiction between the social development demand and environment protection: How to coordinate the compromise between industrial and agricultural development and ecosystems protection? How to coordinate the compromise between upper and lower reaches basin development scale? How to protect eco-environment of the basin and suit the idea of sustainable development?

According to the quantitative study method above (for details, see reference [7]), the authors have gotten the eco-environmental control plan of the basin, as Table 1. The conclusion has been used to guide the local government to manage water resources, protect and control the eco-environment of the basin.

Table 1 The scheme of eco-environmental control plan in Bosteng-Lake basin

Control Variables	Unit	Control Value
Economic structure adjustment:		
(1) Industry		(1) Increase rate per year before 2020: 1.3%
(2) Agriculture		(2) Decrease rate per year before 2020: 1.1%
The measures of protecting eco-environment:		
(1) Artificial raising reed area	10^4 ha M	(1) 0.25
(2) Water table of the big lake		(2) Adjustment table：1,045—1,047.5 Average table：1,046
(3) The ratio of east branch to west brunch at Bolangsumu Diversion structure		(3) 66:34—68:32
Coordinate water usage:		
(1) Irrigation water from the Kaidu river		(1) In the near future (about 2000)：9.3—8.5
(2) Output of groundwater	10^8	(2) In the specified future (about 2020)：5.8 In the near future (about 2005)：3
(3) Inflow to Kongque river	m^3/year	(3) In the specified future (about 2020)：5 13—18

5 Conclusions: the eco-environmental control models of small basin in arid land

According to the characteristics of numerous small basins in arid land and research experiences of typical basin (such as Bosteng Lake basin), in view of eco-environmental comprehensive management of small basin in arid land, the paper has summed up the main control models: Coordinate-Model and Dispose-Water-Model.

"Water resources suitable utilization, and ecosystems effective protection, and coordinative development of soc-economy and eco-environment" is taken as the goal of "Coordinate-Model".

Dispose-Water-Model takes "water resources optimum distribution" as base and goal.

According to above discussion (Fig.1) about water resources formation and transformation, and the structure characteristics of ecosystems, we can give general decisions for eco-environmental control of small basin in arid land. Its details are as follows:

(1) To harness the mountainous areas for conserving water and for maintaining water sources is "**a prerequisite**".

(2) To utilize water resources rationally for maintaining a stable ecology, and to construct the artificial oasis for improving the living and development environment are "**the objective**".

(3) To protect the natural vegetation for making it play a role of protective screen, and to control land desertification for alleviating its harmfulness, and to assure ecological demand for water resources for bringing ecological efficiency well are "**the basis**".

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