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Development Strategies for the Utilization and Protection of Water Resources in the Qinba Mountains

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Abstract: This paper analyzes current situation and existing problems in the protection and utilization of water resources in Qinba Mountains, proposing overall development ideas, objectives, tasks, and corresponding measures with regard to the strategies that could be undertaken to better protect and utilize the water resources. These strategies include ① hastening the development of laws and regulations and finalizing supporting policies; ② strengthening water conservancy based on laws and the strict implementation of restrictive regions; ③ reforming the present watershed management mechanisms; ④ refining the ecological compensation system; ⑤ enhancing the development of water-quality monitoring and warning systems; ⑥ establishing an emergency response system for large water pollution events; and ⑦ developing an innovative economic development model for water based on resource advantages.
Keywords: Qinba Mountains; water resource utilization; water resource protection; strategic study

1 Introduction

The Qinba Mountains have abundant and good quality water resources. This region is the fountainhead of the Danjiang, Hanjiang, and Jialingjiang Rivers, as well as the Duhe, the largest tributary of the Hanjiang River [1]. According to surface water data from water resource bulletins, the total amount of water flowing from the Qinba Mountains to the Yangtze River, the Yellow River, and the Huai River is 1.5×10^{11} m^3, that flowing to the Yangtze River is 1.4×10^{11} m^3, and that flowing to the Yellow River is 7.0×10^{9} m^3. Furthermore, the Qinba Mountains are the water source for the middle line of the South-to-North Water Transfer Project, which distributes water to various ecologically sensitive regions such as water conservation areas, biodiversity preserves, primitive areas, and water and soil conservation areas. Although the water resources of the Qinba Mountains are relatively abundant, the water resource environment is not ideal. There is tremendous pressure for additional ecological protections and growing conflicts between conservation efforts and development activities.

Based on investigation work, this study analyzes the current situation in the Qinba Mountains with regard to the protection and utilization of its water resources and identifies existing problems in the region. This study also proposes strategic ideas, objectives, and relevant measures to ensure water resource sustainability, such as the development of an ecological compensation system and the strengthening of water-quality monitoring and warning systems.

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2 Current status of water protection and utilization in the Qinba Mountains

2.1 Current status of water resources

The Qinba Mountains are vast in territory and rich in water resources. According to survey statistics, there are 254 rivers with a watershed area of 5–100 km^2, 93 rivers with a watershed area of 100–1000 km^2, and more than 10 rivers with a watershed area of more than 1000 km^2, such as the Baohe River and Shuihe River, which are located on both sides of the main stem of the Hanjiang River. These abundant surface water resources make the Qinba Mountains a water sufficient area.

Based on water data from water resource bulletins, the quantity of water resources in the Qinba Mountains in recent years was estimated, and the results are summarized in Table 1; the annual quantity of water resources at the provincial level is presented in Fig. 1. The water resources of the Qinba Mountains are unevenly distributed in time and space, with wide variations in different provinces. The quantities of surface water, ground water, and total water resources show a downward trend annually, which is reflective of the significant negative impact of anthropogenic development activities.

2.2 Current status of water environment

2.2.1 Monitoring water environment

According to survey statistics provided by the local environmental protection and water conservancy departments, 20 hydrological stations were set up along the main stem and tributaries of the Hanjiang River by the drainage-basin hydrographic office and local water conservancy departments. Along the Danjiangkou Reservoir basin and its upper valley, the water conservancy departments set up 73 sections for monitoring the water resources and environment. Furthermore, the China National Environment Monitoring Center set up 49 sections for monitoring water quality—12 in Shaanxi Province, 24 in Hubei Province, and 13 in Henan Province, while the local environmental authorities set up 63 sections for monitoring the water resources and environment.

2.2.2 Water environment quality

From 2011 to 2014, the water quality of the Hanjiang River in the Qinba Mountains was mostly maintained at Grade II (lower grades reflect better water quality), while the water quality in the other rivers either met or was better than the Grade III standard. Moreover, there were no obvious changes in the water quality between the upstream and downstream reaches of the Hanjiang River. The water quality of the Three Gorges reservoir and its upper reaches was excellent in general. However, the water in the tributaries was lightly polluted, with the water quality in several sections in the Pudu River, Sancha River, Fuxi River, and Wuqiao River being worse than Grade V. The water quality of the Danjiangkou Reservoir and its upper valley reaches was also excellent in general, with only a few local channels showing poor water quality. The water in the catchment areas was mainly at Grade I and Grade II. Spatial differences in water quality were

Table 1. Current situation of water resources in the Qinba Mountains*.

	Quantity of water resources ($\times10^8$ m^3)				
	2010	2011	2012	2013	Annual average
Quantity of surface water	1 245.4	1 355.5	1 017.13	953.46	1 095.3
Quantity of ground water	341.2	357.4	321.7	303.8	348.15
Total quantity of water resources	1 363.9	1 487	1 123	1 048.5	1 252.3

* There is some repeated parts in the date between the ground water and surface water according to water resource bulletins.

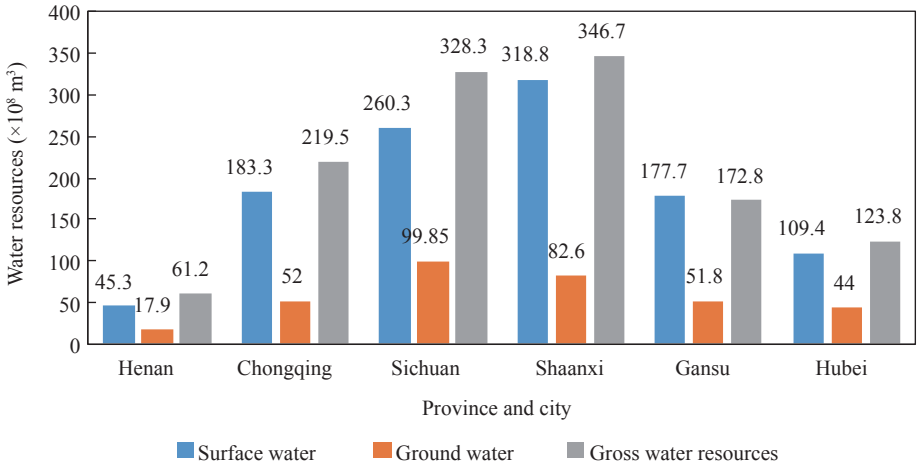

Fig.1. Annual water resources in the five provinces and one city in the Qinba Mountains.

very apparent—the water-quality monitoring sections along the upstream tributaries and reservoirs were mostly Grade I or Grade II, while some reaches along the estuaries were Grade III or worse than Grade V, which indicates that the water quality of the upstream tributaries and reservoirs was better than that of the estuarine areas. The water quality of the Jialingjiang River was mostly maintained at Grade II and Grade III, which met the basic planning requirements. The water quality in the Yellow River basin within the Qinba Mountains region was good, while water in the upstream areas could reach up to Grade II. Some of the tributaries were polluted, such as the Weihe River in Tianshui and the Haoyanghe River in Luoyang. A few reaches were heavily polluted, such as the Hulu River and the Hongnongjianhe River. On the whole, the water quality of the Qinba Mountains was good, with only some sections showing evidence of pollution.

2.3 Current status of water resources development and utilization

2.3.1 Domestic, industrial, and agricultural water

Based on water consumption data from water resource bulletins, the volume of water consumption in the Qinba Mountains was estimated, and the results are presented in Table 2. The proportion of agricultural water consumption was the largest at more than 50%, which was mainly due to the fact that agriculture is the major industry in the Qinba Mountains. The low degree of mechanization and modernization of production, water wastage, and minimal large-scale water-saving irrigation practices were some factors leading to the higher proportion of agricultural water consumption. Because industry is under-developed in this region, the volume of industrial water consumption was about half of the agricultural water consumption. As a result of the low standard of living, domestic water consumption was relatively small.

2.3.2 Hydropower resources development

Because of the distinct natural geographical conditions, there are rich hydropower resources in the Qinba Mountains. Hence, this aspect is being prioritized in the current development plans for the utilization of water resources. According to survey statistics provided by local departments, there are presently 83 hydropower stations with an installed capacity of more than 1×10^4 kW. Among these, there are eight large hydropower stations with a total installed capacity of 5.245×10^6 kW, 37 mid-sized hydropower stations with a total installed capacity of 3.9275×10^6 kW, and 38 small hydropower stations with a total installed capacity of 8.525×10^5 kW. In order to support the development of hydropower resources, a large number of reservoirs have been built in the Qinba Mountains. Among the 62 mid-sized or larger reservoirs in our survey, the numbers of large Class I reservoirs, large Class II reservoirs, and mid-sized reservoirs are nine, 30, and 23, respectively.

2.3.3 Inter-basin water transfers

In order to use the rich water resources in the Qinba Mountains to their full potential and alleviate the water resource crises in Beijing, Tianjin, Shaanxi, and North China, the government has implemented 10 major inter-basin water transfer projects, which include the middle route of the South-to-North Water Transfer Project, the Hanjiang-to-Weihe River Project, and the Xi'an Heihe Water Diversion Project. The middle route of the South-to-North Water Transfer Project is much larger than the other water transfer projects in our survey based on the associated water quantity, water diversion scope, and management complexity. Because of the lower quantity of water diverted, smaller corresponding scope, and simpler management institutions, the smaller projects such as the Hanjiang-to-Weihe River Project do not have interprovincial coordination problems.

3 The problems associated with water protection and utilization in the Qinba Mountains

3.1 Low efficiency in water resources utilization and need for improvements in the distribution system

Although the Qinba Mountains are rich in water resources, the rate of water resources utilization is low. The rate of utilization of surface water was only 28%, while that of ground water was 45%, according to data from water resource bulletins. At present, the gap between the demand and supply is not prominent. However, the water distribution system needs to be perfected as soon as possible. For example, in Henan Province, the sources of the water supply were surface water and ground water. Once the South-to-North Water Transfer Project began,

Table 2. Current status of water consumption in the Qinba Mountains.

	Volume of water consumption ($\times10^8$ m^3)		
	2011	2012	2013
Domestic water consumption	30.49	32.45	34.59
Industrial water consumption	52.73	56.37	54.21
Agricultural water consumption	99.47	99.82	101.36
Total water consumption	184.92	189.57	191.09

Note: In addition to domestic, industrial and agricultural water, total water consumption usually also includes about 1% of the ecological environment water replenishing which is not be listed here because of its low volume.

water transfer of good quality was included in the water supply; however, this is problematic because a part of water transfer was used for agricultural irrigation.

3.2 High risk for river pollution

3.2.1 Serious local river pollution

The overall water quality in the Qinba Mountains was good. However, the pollution in some rivers such as the Tianhe River in Shiyan, the Laoguanhe River in Nanyang, and the Weihe River in Tianshui was very severe. Additionally, a high concentration of industries in the upstream regions of the Hanjiang River is causing problems pertaining to industrial pollution from pharmaceutical manufacturing, food brewing, chemical industries, and other major industry; this pollution impacts on both the Hanjiang River and its tributaries. Lastly, illegal sewage discharges as well as excessive and underlying blowdown (the drawdown of reservoirs) have made the water quality in several rivers worse.

3.2.2 Increases in rural and agricultural non-point source pollution

The rate of proper treatment of rural sewage and livestock wastes is very low, and direct discharges of such nutrient laden waste water into rivers has caused problems with eutrophication [2]. Moreover, improper use of pesticides, fertilizers, and mulching film in the farming industry has worsened the soil pollution situation; these residues are ultimately discharged into rivers as a result of soil erosion. Thus, the threat from rural and agricultural non-point source pollution cannot be ignored.

3.2.3 Numerous tailing ponds with lagging surveillance

The Qinba Mountains are rich not only in water resources, but also in mineral resources. Within the mineral-rich areas, many mining and mineral processing businesses have been established. As a result of hasty and poor construction, there are multiple tailing ponds, waste-rock yards, and spoil areas that pose serious risks to the region's water resources. This situation is being exacerbated by the lack of environmental protection facilities and security for the infrastructure. Waste slag containing sulfur, arsenic, mercury, and other harmful elements may contaminate ground water during the infiltration of toxic leachate. Until now, sufficient online monitoring systems for tailings have not been set up and synthesis databases have not been established. Therefore, it is difficult to comprehensively evaluate the overall regional environmental risks accurately. The lack of ownership for the tailings and their proximity to rivers and reservoirs makes this a dangerous situation, as accidental spills could easily occur, which would represent serious threats to the security of the watershed.

3.2.4 Intense rocky desertification and soil erosion

The areas experiencing intense rocky desertification in the Qinba Mountains include the Three Gorges Reservoir Region and the Danjiangkou Reservoir Area. The total area under desertification in the Three Gorges Reservoir Region is 6 680 km^2, and the incidence of rocky desertification is 10.8%. The total area under desertification in the Danjiangkou Reservoir Area is 4 620 km^2, and the incidence of rocky desertification is 10.0%. Rocky desertification directly intensifies the phenomenon of soil and water loss in the region. As one of the regions with the most serious soil erosion problem, the area impacted by soil erosion in the Three Gorges Reservoir Region has reached up to 2.7×10^4 km^2, and the annual amount of sediment loss was estimated at 1.4×10^8 t, which accounts for 26% of the sediments in the upper Yangtze River. The area impacted by soil erosion in the Danjiangkou Reservoir Area has reached up to 1.9×10^4 km^2, and the annual amount of sediment loss was estimated at 9×10^7 t. Because of disturbances from human activities such as farming in slope cropland, land desertification in the region has intensified. The low degree of control over soil erosion and the excessive reclamation of land by traditional agricultural activities also have further aggravated the problem of soil erosion. In relation to categories of soil erosion intensity, areas with light erosion and micro erosion amount to 68% and areas with intensive erosion, very intensive erosion, and severe erosion amount to 21.6%. All these factors pose a certain threat to the stability of the regional ecosystems and water conservation. The above-mentioned data were provided by local departments.

3.3 Deficiencies in water-quality monitoring and early warning systems

3.3.1 Partly repetitive and inadequate monitoring stations

For the Danjiangkou Reservoir, the Hanjiang River, and the Danjiang River, multiple water-quality monitoring sections have been set up, with control sections on important nodes. Some sections are even located in the tributary inlets and upstream areas. However, the sections set up by environmental protection system are not identical with that set up by water-conservancy system, so monitoring parameters are different, which leads to gaps in the database. Moreover, automatic water-quality monitoring stations are lack at present; some of the online automatic water-quality monitoring stations are partly repetitive and insufficient in remote areas. These inadequacies need to be addressed so that accurate data can be collected on the current situation and used to assess the changing trends of water quality.

3.3.2 Relatively retrograde infrastructure and methods for environmental regulation

Artificial monitoring continues to be the main method of monitoring water quality in the Danjiangkou Reservoir and its upstream areas. Only two official online automatic water-quality monitoring stations exist within the whole basin. Presently, there exist great differences between reality and the planning objectives for remote automatic water-quality monitoring infrastructure, such as site locations, quantities, and equipment configurations [3]. Hence, onsite inspections are the only means

of environmental supervision in the reservoir and upstream areas. However, this supervisory means is onefold, authorized size of monitoring personnel is difficult to meet the requirements of national environmental monitoring standardization, and this is not matched up with the overall environmental protection requirements in the central water source area of the middle route of the South-to-North Water Transfer Project. The slow pace of construction of the environmental emergency center has also made it difficult to guarantee emergency monitoring of water quality during critical incidents. Furthermore, installation of facilities for the online monitoring of pollution sources is also not complete. Therefore, pollution sources could be a major threat to the security of water resources.

3.3.3 Weak systems for early warnings and forecasts of the water quality

The database on sources of risk to the water resources and environment for the whole basin has not been set up yet, and the information transmission system needs to be improved. Presently, it is unable to carry out real-time monitoring and generate effective early warnings about pollution from key sources during water pollution accidents.

3.4 Need for improvements in the ecological compensation mechanism

3.4.1 Lack of unified compensation standards and inadequate compensation

State and local governments have formulated some systems and measures for ecological compensation aimed at the Danjiangkou Reservoir and its upstream areas in recent years. However, several problems were encountered in the current implementation process, such as low, non-uniform costing standards and inadequate remedies. Overall, there continues to be a big gap between the amount of transfer payments for the preservation of national key ecological function areas from the central government and the environmental protection investments made by local governments. The former has thus neither fully supported the water quality protection measures in the Danjiangkou Reservoir and its upstream areas to date, nor has it ensured the smooth operation of water diversion projects.

3.4.2 Single mode for ecological compensation and funding

The main source of compensation in the Danjiangkou Reservoir and its upstream areas is intended to be transfer payments for national key ecological function areas from the central government. Regional ecological compensation mainly relies on government fiscal subsidies and administrative controls such as monetary compensation, substance compensation, and policy compensation [4]. The current ecological compensation measures and policies adopted by the nation were mainly focused on investments in development projects such as water pollution control projects and water and soil conservation projects. However, without full funding, incomplete investment projects are always of a lower standard [5]. Ecological compensation funds are mainly sourced from the general financial transfer payments from the central government. In addition, the lack of horizontal compensation mechanisms has meant that there was only a single source of funds.

3.4.3 Need for improvements in ecological compensation policies and regulations

An ecological compensation policy aimed at the Danjiangkou Reservoir and its upstream areas has not been formulated and established. Furthermore, the relevant laws and regulations that do exist neither define the rights, obligations, and responsibilities of the stakeholders for water resource protection, nor do they stipulate the compensation content, methods, standards, and implementation measures clearly and specifically.

3.4.4 Need for improvements in the evaluation mechanism

Although a series of incentives and constrained policies have been formulated, their authority is not binding enough, and this has led to embezzlement and abuse of the special funds.

3.5 Need to further explore the advantages of developing a water based economy

Because of the special geographical conditions and excellent ecological environment, the Qinba Mountains represent an ecological security preserve of national importance. The precipitation in most regions is relatively abundant, and water resources in most regions are rich, diverse, of good quality, and display stable flows. There are suitable water sources available for scaling up. In 2011, the largest rich-selenium mineral water production base located in Ankang was completed and put into operation, while in 2015, the Danjiangkou water source was selected in the first batch of “China water” water sources. At present, there are several well-known mineral water brands from the Qinba Mountains, such as Shangluo Weiyang, Ankang Kangxi, Baiyun Dukang, and Hanzhong Yunwushan. However, the present domestic bottled water market has been occupied by a few large enterprises such as Tingyi, Wahaha, Nongfu Spring, and Robust. Thus, it has proven difficult to create a new and uniform drinking water brand with Qinba features in the short term.

4 Development strategy

4.1 The overall idea of development

4.1.1 Conservation priorities

The ecological control red line and multi-stage environmental targets should be delimited, guidance should be provided for a reasonable industry layout, an Action Plan for Water Pollution Prevention and Control should be actively implemented. In addition, the formulation of relevant laws involving water dispatch in Qinba Mountains, environmental function zoning,

quality goal management, source protection of drinking water, ecological flow security, and marine and land-based pollution prevention and control should be accelerated. Relevant supporting policies, laws, and regulations should be implemented for the protection of the ecological environment and comprehensive pollution controls in the Qinba Mountains. Designs at the top-level should be accelerated, and water environment management should be reformed from district management to valley management and the integrated management of "mountains, water, forests, fields, and lakes".

4.1.2 Innovation support

Innovation should be based on the green-development concept and guide the development activities. The triple transformation of economic, social, and environmental developments should emphasize a circular economy and clean production. Restrictions should be set to guide industrial developments. Transformation development should be adopted instead of development based solely on short-term goals. Recycling of industrial waste should be implemented. Green agriculture and ecological agriculture industrial chains should be built and chemical fertilizers and pesticides should be used effectively. Recycling of agricultural and rural waste should also be promoted, and water pollution from rural non-point sources should be reduced. Green life philosophy should be advocated, lifestyles should be transformed, and sewage and waste discharges should be reduced in all areas.

4.2 Strategic objectives

A water-quality monitoring and early warning network should be established properly. The water resource management mechanisms and compensation systems for the conservation and utilization of water resources should be built based on scientific principles. Advanced technology for water resource conservation and emergency response should be implemented by around 2020. An economic development model based on water resources with good quality should be developed, ecological remediation work to counter desertification should be carried out, and a technology platform for the green development of water resources as well as an ecological model promoting harmony between mankind and water resources should be established by 2030.

4.3 Strategic missions

4.3.1 Perfecting relevant laws and regulations

Laws and regulations regarding the inter-basin water environment management system within China, which address issues such as water dispatches, environmental functional district planning, quality goal management, drinking water source protection, ecological flow security, and marine and land-based pollution prevention and control should be established and improved upon.

4.3.2 Perfecting compensation systems and funding mechanisms

An ecological compensation method based more on marketization should be explored, and a regional common development mechanism should be set up. In addition to financial compensation, technological compensation or intellectual compensation and industrial compensation should also be provided [6]. A number of highly qualified and talented groups should be invited to participate in ecological development activities, including scientific and technological talents, senior artisans, and talented managers, as this will improve the overall level of modernization [7]. Water source regions should be subsidized to allow for the development of alternative, pollution-free industries. Industrial transfers and undertaking platforms should be built; resource-based industries, labor-intensive industries, and low polluting industries should be promoted in conjunction with advanced technologies to allow for the formation of industrial zones and clusters.

4.3.3 Developing advanced water monitoring and early warning networks and emergency response technology

Based on cloud computing technology, a comprehensive information system with automatic monitoring, early risk warning, business management, and public service capacities should be built for the entire basin. A special fund should be set up to improve early warning and emergency responses aimed at sudden water pollution accidents, extreme weather events, natural disasters, and non-traditional threats to security such as terrorist attacks.

4.3.4 Developing a green industrial technology to guarantee water quality

Based on advanced biotechnology, materials, and other types of green technology, traditional industries should be transformed so as to reduce the damage to water resources and the environment. At the same time, water security will be equally important to consider.

4.3.5 Promoting the development of water resources economy

Hydropower resource development should be reduced. Instead, the focus should be on the development of a value-added, high-quality water resources economy and the development of an economic model for ensuring high-quality water resources with reasonable usage amounts.

5 Safeguard measures and policy recommendations

5.1 Accelerating the development of laws and supporting policies

The legislation of top-level designs and plans for the Qinba Mountains should be accelerated to ensure that the management

agencies, local governments, businesses, and society can coordinate their activities with uniform regulations. The State Council should consider bringing the Qinba Mountains into the prevention plans for national key river basins, which are aimed at reducing water pollution and promoting water quality and water resource legislation and implementation at the national level; such efforts could include Qinba Mountains Water Environmental Function Zoning, Qinba Mountains Water Resources Utilization and Conservation, or Qinba Mountains Water Pollution Prevention and Control, which should be enacted by the National People's Congress of the People's Republic of China.

During the process of legislation, the following problems need to be paid more attention to. First, there is the institutional problem. The existing management system should be optimized, the authority–responsibility relationship between the management agencies and local governments should be clearly defined, and a mechanism for counterbalance and oversight should be set up. The second problem involves coordination among the several inter-district mechanisms, and tasks to be addressed involve the standard management of border- section water quality, emergency coordination for the remediation of pollution accidents, water-environment security assurance and early warning. The last key issue involves the binding problems. The total water consumption and the dispatch of key water source areas such as Danjiangkou Reservoirs should be regulated properly. Agencies need to ensure that utilization activities conform to the requirements of the water functional area protections and that the control sections of the main inflow channels meet the water quality standards.

5.2 Harnessing water according to the law and strictly controlling within the "red line"

The idea of harnessing water according to relevant laws should be firmly established, and all management activities including performance, decision, holding power, and supervision activities should be carried out as per the law. Actions should be taken based on the Action Plan for Water Pollution Prevention and Control released by the State Council, while ecological "red line" requirements should also be implemented. The formulation of an ecological control line map should be accelerated within all regions, especially the upstream areas. The ecological line scope including forbidden development zones and strictly controlled zones should be detailed. The pollution from inflows should be strictly evaluated in water functional areas along with the establishment of intensive supervision of sewage outlets on rivers and drinking water sources. Relevant objectives should be incorporated into the assessment reports of the government, such as water quality up to standard, standard development for drinking water resources, compliance with ecological water requirements, and reductions in groundwater withdrawals.

5.3 Reforming the management mechanisms

The government should learn from the experiences of the European Union, which manages the Rhine and Danube, as well as the US, which manages the Tennessee valley, during their set up of inter-regional specialized agencies. Normalized mechanisms of interactive cooperation and negotiation between the provinces and different stakeholders need to be established as soon as possible, as these will be useful for coordinating water demands among diverse regions, departments, and industries. Regional cooperation should be strengthened in the various provinces and cities, along with actively exploring the new collaboration mechanism of "alliance between governments" in the inter-regional management process. In this manner, and with the gradual expansion of the application range, a collaboration mechanism can be established that caters to the entire Qinba Mountains region, thereby facilitating the trans-provincial work involved with water resource utilization and environmental protection.

5.4 Improving the ecological compensation system

First, an accounting method for ecological compensation standards should be established based on monitoring results and evaluations of the ecological environment, water quality conservation goals, important ecological functions, the demands of natural resource conservation and ecosystem service functions, as well as environmental costs. Several factors should be taken into consideration in the study of the accounting method for ecological compensation standards, including the reservoir area, flood area, population size, impact on water quality, per capita resources, immigrant resettlement patterns, damages from enterprises being shut down, and contributions for engineering developments.

Second, a mechanism for negotiation and mutual development needs to be built. Co-construction and sharing mechanisms should be established for ecological protection efforts between water-supply areas and water-receiving areas. The care-takers and beneficiaries should be encouraged to realize reasonable ecological compensation through voluntary negotiation. Government management platforms should be built, and the establishment of water diversion compensation mechanisms should be promoted. With financial aid, technical assistance, and trade cooperation, water resource protection zones should be promoted by developing a circular and ecologically based economy.

Third, market-oriented ecological compensation models should be actively explored, such as water rights trading systems. By opening such a market, the water resources and environment can be capitalized upon to achieve the dual goals of reducing pollution and economizing resources [8]. Reasonable allocation and paid use systems for water resources should be improved, with the establishment of transfer and lease trading mechanisms for the right to use water, as well as the implementation of emis-

sions trading under the control of the government. For the Danjiangkou Reservoir and its upstream areas, based on case studies of successful experiences, water right trade models should be explored between water-supply areas and water-receiving areas, as well as among different industries and diverse users to achieve the optimal allocation of regional water resources.

Lastly, the policy system of ecological compensation should be improved. Policies and laws should be developed and comprehensive factors of ecological compensation should be defined to achieve the unity of rights, obligations, and interests; factors that need to be considered include the basic principles, main focus areas, beneficiaries, scope of compensation, compensation standards, funding sources, rights and obligations of the stakeholders, calculation methods, and responsibilities. The assessment methods for compensation fund distribution should be improved to realize reasonable distribution of the transfer payments for key ecological function areas from the central government.

5.5 Strengthening water-quality monitoring and early warning efforts

First, the monitoring sites established by the environmental authority and water conservancy office should be integrated, and the layout of these sites should be optimized. Taking all factors into consideration, such as the natural environmental characteristics, water environment function areas, pollution distribution characteristics, hydrology, sampling accessibility, social and economic characteristics, and management practices, the monitoring sections should be screened and optimized to achieve spatial representativeness, operability, and historical continuity. At the same time, it should be ensured that these water-quality monitoring sites are consistent with the national monitoring network system.

Second, the development of water quality automatic monitoring stations should be promoted. In addition to the two automatic monitoring stations and 49 monitoring sections in existence, additional automatic monitoring stations should be set up on the main tributaries of the Hanjiang River, the key control sections, the inlets of tributaries with serious pollution problems, and other tributaries with high pollution risks. Online monitoring equipment should be installed in enterprise outfalls with key pollution sources so as to achieve effective and accurate supervision and timely warnings of water pollution accidents.

Third, the development of monitoring institutions and water-quality monitoring capacity should be improved. In accordance with the national environmental monitoring requirements for standardized construction, the development of monitoring institutions should be improved in the reservoir area and its upstream reaches. Inter-regional water quality management organizations should be explored, and the proportion of full-time personnel should be increased to guarantee the accuracy and authority of the water-quality monitoring results. Appropriate water environment emergency centers should be established in regions with higher environmental risks. The capacity for emergency monitoring should be improved to guarantee regional water quality security.

Lastly, a monitoring and early warning system should be established. Work involving the investigation, identification, classification, evaluation, and analysis of regional water pollution risk sources should be carried out. The present water quality situation should be better understood with appropriate monitoring methods. Through the deployment of water quality models, the temporal process of water quality change should be simulated to allow for dynamic monitoring and trend forecasts.

5.6 Establishing emergency response mechanisms for water pollution accidents

First, insurance funds should be set up for the prevention of water pollution accidents. The funds should be provided by the provinces in the Qinba Mountains, with each province also setting up insurance funds at the provincial level. The funds should mainly be used to resolve sudden pollution accidents that may occur, which will necessitate loss compensation and treatment. Each province could make average contributions initially, the ratio of which could be adjusted based on the accident location at a later date.

Second, innovations should be made with regard to emergency treatment technology. Research should be carried out on composite control technology and process optimization, and combined purification methods should be explored to achieve key technological processes that are fast, efficient, and stable for sudden pollution control. To this end, research and development activities for emergency water treatment equipment with desirable attributes (e.g., automated, small working area, mobile, efficient) should be carried out.

Third, pollution prevention and monitoring should be improved. For unconventional water pollution problems caused by the development of associated minerals, a database should be set up to provide information support [9]; this database could include unconventional hazardous pollution categories, the geographical location of key enterprises who use or produce hazardous goods, chemical properties, laboratory monitoring methods, emergency monitoring and treatment protocols for hazardous goods, and subject matter experts. Moreover, information sharing platforms should be established by environmental authorities and water conservancy offices in a collaborative manner, thus achieving interconnectivity among different emergency command platforms.

5.7 Innovating with water economy development models based on resource superiority

The development of water as a commodity is an effective way to scale up the water economy. A survey of current mineral water resources should be carried out to determine their distri-

bution, type, and reserves, as well as to set up mineral water production bases that are natural, healthy, and of a high quality. By attracting foreign investments, large beverage production enterprises at home and abroad should be encouraged to build factories. By relying on large enterprises to drive small businesses, the development of the natural water industry cluster should be promoted and rapid industry growth should be facilitated. At the same time, series of functional mineral water beverage products should be developed to overcome the lack of variety. Specifications for reorganizing and restructuring the optimization of existing water commodity enterprises should be carried out. Small water commodity businesses should be encouraged to join together, thus forming a uniform standard and brand, which could lead to a market advantage.

Areas with abundant high-quality water resources should prioritize their supplies of different-quality water [10]. Starting from the water resource, industrial water factories and domestic water factories should be built. The industrial factories should use river water for industrial production, while the domestic water factories should use good quality reservoir water for urban and rural residents. A good quality water supply network should be established in areas with water shortages, with distributing stations set up in each village or community along the way and water pipes connected to each house, while making complete use of water metering and payment mechanisms.

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