

Research on Water Resources Value Accounting and Compensation Mechanism in the Chengdu-Chongqing Twin-City Economic Circle

Zhenyi Liu

College of management, Sichuan University of Science & Engineering, Yibin, Sichuan, China

Abstract: This article aims to explore the current situation, challenges, and optimization strategies of water resource value accounting and compensation mechanism in the Chengdu Chongqing economic circle. As an important national level economic circle in western China, the management and protection of water resources in the Chengdu Chongqing Economic Circle is of great significance for the sustainable development of regional economy and the protection of ecological environment. Firstly, this article analyzes the current situation and characteristics of water resources in the Chengdu Chongqing economic circle, and sorts out the distribution, utilization, and existing problems of water resources in the region. Next, this article focuses on the theory and methods of water resource value accounting. Drawing on advanced experience in water resource value accounting at home and abroad, combined with the actual situation of the Chengdu Chongqing economic circle, the GEP accounting method is used to evaluate the economic value, ecological value, and social value of water resources, providing important basis for the rational allocation and effective protection of water resources. On this basis, this article delves into the construction and improvement of water resource compensation mechanisms. In response to some problems in water resource management in the Chengdu Chongqing economic circle, the idea of establishing and improving a water resource compensation mechanism has been proposed. In the process of mechanism construction, emphasis is placed on the combination of government guidance and market mechanisms, and various methods such as fiscal subsidies, tax incentives, and water rights trading are used to incentivize water resource conservation and ecological protection and restoration. At the same time, we will strengthen coordination and cooperation across regions and watersheds, and promote the formation of a water resource protection pattern of joint construction, governance, and sharing. Finally, this article proposes policy recommendations for improving the value accounting and compensation mechanism of water resources in the Chengdu Chongqing economic circle. Suggest strengthening the construction of water resource management regulations and improving the system of paid use of water resources; Increase investment in technology and talent cultivation to improve the accuracy and scientificity of water resource value accounting; Strengthen publicity and education to enhance public awareness of water resource protection; Promote cross regional and cross basin cooperation and sharing of water resources, and jointly address the challenges of water scarcity and ecological degradation.

Keywords: Water Resource; Chengdu Chongqing Economic Circle; GEP Accounting Method; Compensation.

1. Introduction

1.1. Research Background

Since 2010, the concept of "green development and sustainable development" has gradually become the focus of global attention and the trend of The Times. In 2015, the Fifth Plenary Session of the 18th Central Committee of the Communist Party of China elevated green development to the height of a national strategy and regarded it as one of the five major concepts for promoting development. The Fifth Plenary Session of the 19th Central Committee of the Communist Party of China held in 2020 further reaffirmed the sustainable development strategy, emphasizing the need to achieve a comprehensive green transformation of the economy and society, strengthen environmental governance, improve resource utilization efficiency, and enhance the stability of the ecosystem. The 2021 government work report also emphasized the need to further advance the sustainable development strategy and promote the transformation of production and lifestyle to a green model. "Green" has gradually become a basic requirement for China's economic and social development, and all regions regard enhancing the level of green economic development as a key task. As a key component of natural resources, water resources are undoubtedly an important starting point for developing a

green economy. The southwest region located in the upper reaches of the Yangtze River not only constitutes a natural barrier for the ecological environment of the middle and lower reaches of the Yangtze River and even the whole country, but also, due to its unique ecological status and vulnerability, it is of great significance to conduct in-depth research on the green economic efficiency of this region.

As the world's largest developing country, China's economy has grown miraculously since the beginning of the 21st century. It is now the world's second-largest economy after the United States. The rapid growth of China's economy poses a huge challenge to its development. However, it is generally believed that due to the loose economic environment, the rapid growth of China's economy has been greatly affected. The rapid growth of China's economy is generally believed to be caused by the loose economic environment. The extensive mode of economic development has led to a rapid increase in China's economic aggregate. However, it is the development mode of "polluting first and treating later" that has caused huge damage to the environment. The economic growth mode characterized by low resource utilization rate, high pollution, high consumption and low efficiency has mostly come at the cost of environmental pollution and resource waste in China's past economic development, and has gradually become a

bottleneck restricting economic growth.

1.2. Research Significance

Since the 18th National Congress of the Communist Party of China, the Party has incorporated ecological civilization construction into the strategic layout of the "Five-Sphere Integrated Plan", and has stated that the ultimate goal is to coordinate the relationship between humans and nature, to ensure the sustainable supply of ecosystem services for social needs, and thereby to enhance human well-being. Since the 13th Five-Year Plan, the economic development of the Chengdu-Chongqing Twin-Circle has entered a fast lane, becoming an important engine for economic and social development, ecological civilization construction, reform and innovation, and opening up in the western region. It has presented a favorable situation where the two cores of Chengdu and Chongqing move towards each other and jointly lead the high-quality development of the region. We should adhere to the principle of ecology first, take green development as the principle, pay attention to improving the quality of the ecological environment, and continuously promote the in-depth construction of ecological civilization with high standards and strict requirements. The southwest is not only a region with backward economic development and fragile ecology, but also a rich area of natural resources and ecological environment. In such an environment, the low level of economic development, the acute contradiction between economic development and the ecological environment, the low production efficiency, the large amount of pollution emissions, and the proposal of the green development concept have pointed out a way out for the economic transformation in the southwest region. The low level of green economic development, the prominent contradiction between economic development and the ecological environment, and problems such as low production efficiency and large amounts of pollution emissions exist. As the main force of economic development in the southwest region, Sichuan and Chongqing have an even greater obligation to take the lead in launching a green economic transformation mainly based on the utilization of natural resources. The southwest region is an underdeveloped and ecologically fragile area in the west. The protection of the ecological environment and the high-quality development of the economy are both inseparable from the development of the green economy. Taking the Chengdu-Chongqing Twin-circle as the research area and each district and county within the region as the basic units, with the aim of enriching the research content of the green economy of water resources within the region, the research on the green economy mainly based on water resources within the region is conducted.

2. Research Review

Ouyang Zhiyun et al. were the first to propose the concept of Gross Ecosystem Product (GEP) and constructed the corresponding research framework, laying a solid foundation for the formation of the GEP system. Yang Hailong et al. quantitatively evaluated the current development status of the regional ecological environment through the GEP accounting method, which can also provide reference and inspiration for the sustainable development planning of the ecological environment. By sorting out and analyzing the quantity, quality, distribution and other characteristics of important natural resources such as water, land, biology, minerals and energy in the Chengdu-Chongqing Twin-City Economic

Circle, Chen Yanni et al. provided a macro basis for the planning and construction of the Chengdu-Chongqing Twin-City Economic Circle, and also offered references for the development and protection of related natural resources. Huang Ao et al. analyzed the water use efficiency of the two major central cities, Chengdu and Chongqing, through the two major methods, namely the TOPSIS method and the VIKOR method, and then evaluated the water-saving potential of the two major central cities, reaching the conclusion that the overall water-saving potential was considerable.

3. Accounting and Assessment of Water Resources Value in the Chengdu-Chongqing Twin-Circle

3.1. Overview of Water Resources in the Chengdu-Chongqing Twin Circles

The Chengdu-Chongqing Twin-City Economic Circle is located in the southwest of China, in the upper reaches of the Yangtze River. It has a vast jurisdiction and is rich in natural resources. This area has been an important agricultural and industrial base in China since ancient times and holds a pivotal position in the country's economic and social development. In recent years, with the in-depth implementation of the national strategy, the development of the Chengdu-Chongqing Twin-City Economic Circle has further accelerated, becoming an important engine for promoting the large-scale development of western China. The Chengdu-Chongqing Twin-City Economic Circle is not only an important convergence point of the Belt and Road Initiative and the Yangtze River Economic Belt, but also the starting point of the New Western Land-Sea Corridor. It enjoys a unique strategic position. The region boasts excellent ecological resources, abundant energy minerals, densely distributed towns and diverse landscapes, all of which have laid a solid foundation for economic development and have become an important growth pole and new power source for promoting high-quality development in the western regions of our country. With the continuous support of national policies, the construction of the Chengdu-Chongqing Twin-City Economic Circle has been in full swing in recent years, and national policies have been constantly introduced.

In 2022, the total water resources in the Chengdu-Chongqing region were approximately 44.381 billion cubic meters, and the total water consumption was about 12.279 billion cubic meters. The overall water resource utilization rate was only 27.67%. This was mostly due to the abundant passing water in the Chengdu-Chongqing region. However, due to the influence of factors such as terrain and climate, the available water resources in the Chengdu-Chongqing region were limited, making its development and utilization very difficult.

The study area shows significant imbalance in the distribution of per capita water resources, and its spatial distribution characteristics are obviously manifested as a pattern of "dual-core trough, upstream peak, and downstream trough". Specifically, due to the dense population in the two core areas of Chongqing and Chengdu, the per capita consumption of water resources is relatively low. On the contrary, in the upper reaches of the region, such as the basins of the Tuojiang River and the Jinsha River, as well as the areas along the Yangtze River near Chongqing in the lower reaches,

the per capita water resource usage is generally high, which reflects the significant geographical differences in water resource utilization.

3.2. Methods for Calculating Water Resources Value

This article mainly adopts the GEP accounting method. The GEP (Gross Ecosystem Product) accounting method is an accounting system for monetizing the evaluation of the value of ecosystem services. This paper studies the water resource value of the Chengdu-Chongqing Twin-City Economic Circle in 2022 based on the GEP accounting model, then conducts research and evaluation on the calculated data, and puts forward specific suggestions. It aims to scientifically understand the potential value of ecosystem services and provide important reference basis for ecological compensation mechanisms, performance assessment of ecological civilization, etc.

The GEP accounting mainly includes several aspects such as the value of material products, the value of regulatory services and the value of cultural services. Specifically speaking, the value of material products refers to the value directly provided by the ecosystem for economic products such as food and water resources. The value of regulating services involves the role of ecosystems, the regulation of climate, the purification of the environment, and the conservation of soil and water. The value of cultural services encompasses non-direct use values, such as entertainment, aesthetics and other services provided by the ecosystem for humanity.

In terms of accounting methods, GEP draws on the accounting framework of GDP (Gross Domestic Product), but it also has its uniqueness. Since many values in ecological services are difficult to be directly reflected through market prices, it is necessary to monetize and evaluate the willingness to pay by measuring people's degree of preference. This requires an indirect approach. Furthermore, scholars have also proposed methods for decomposing and calculating sub-items such as material product supply, ecological regulation services, and ecological cultural services according to the functions of ecosystem services, in order to more accurately reflect the value of ecosystem services.

The data mainly come from local statistical yearbooks, statistical annual reports, water resources bulletins, environmental quality bulletins, etc.

3.3. Accounting of Water Resources Value

3.3.1. Product and Service Value

1. Domestic water

The situation of domestic water use in the Chengdu-Chongqing Twin-City Economic Circle involves multiple aspects such as the allocation, protection, utilization of water resources and cooperation among regions. To ensure domestic water supply, the Chengdu-Chongqing region has enhanced its cross-regional water resource allocation capacity through the construction of major cross-regional water storage, water lifting and water diversion projects, and promoted the formation of a water network system featuring multi-source complementarity and proper water diversion and drainage. For instance, the plan mentions the need to accelerate the construction of major regional water network projects, ensure water supply security, and promote the formation of a water supply network that is mutually beneficial in terms of abundance and scarcity, multi-source complementarity, and

safe and efficient. For instance, the Li Jiayan Reservoir in Chengdu, as the city's "second water source", the construction of the Li Jiayan Reservoir will further enhance the water supply security level of the Chengdu metropolitan Area. This reservoir is based on the Dujiangyan Irrigation Project. By optimizing the allocation of water resources, it enhances the regional water resource allocation capacity.

The domestic water consumption is calculated using the market value method, and the calculation formula is shown in Equation (1). According to the "2022 Chengdu Water Resources Bulletin" and the "2022 Chongqing Water Resources Bulletin", the domestic water consumption of Chengdu and Chongqing in 2022 was 850 million cubic meters and 1.6077 billion cubic meters respectively. The average price of domestic water in that year was 3.37 yuan /m³ and 3.5 yuan /m³ respectively, and the total value of domestic water could be obtained as 2.865 billion yuan and 5.813 billion yuan respectively.

$$VP1=PP1 \times QP1 \quad (1)$$

In the formula: VP1 represents the value of domestic water, amounting to billions of yuan; PP1 represents the water price for domestic use, in yuan per cubic meter. QP1 represents the domestic water consumption, in billions of cubic meters.

2. Industrial water use

Industrial water use refers to the water consumption of the primary, secondary and tertiary industries. As an important economic growth pole in the western region of China, the Chengdu-Chongqing Twin-City Economic Circle has witnessed rapid industrial development and an increasing demand for water resources. The demand for water resources and the quality requirements vary among different industries.

Industrial water consumption is calculated using the market value method, and the calculation formula is shown in Equation (2). According to the "2022 Chengdu Water Resources Bulletin" and the "2022 Chongqing Water Resources Bulletin", the industrial water consumption in Chengdu in 2022 was 3.03 billion cubic meters, 349 million cubic meters, and 667.7 million cubic meters respectively. In 2022, the industrial water consumption in Chongqing was 2.75432 billion cubic meters, 1.82607 billion cubic meters and 4613.1 million cubic meters respectively. The average prices of industrial water use in Chengdu in the current year were 0.084 yuan /m³, 4.2 yuan /m³ and 5.2 yuan /m³ respectively, and those in Chongqing in 2022 were 0.6 yuan /m³, 4.1 yuan /m³ and 4.6 yuan /m³ respectively. After calculation, The total value of industrial water use in Chengdu and Chongqing was 5.19236 billion yuan and 11.26151 billion yuan respectively.

$$\sum VPn=PPn \times QPn \quad (2)$$

In the formula: VPn represents the water value of the NTH industry, amounting to hundreds of millions of yuan; PPn is the water price for the NTH industry, in yuan per cubic meter. QPn represents the water consumption of the NTH industry, in billions of cubic meters.

3. Food supply

The Chengdu-Chongqing Twin-City Economic Circle is rich in agricultural resources and has favorable agricultural production conditions. It is one of the important agricultural production bases in China. The Chengdu-Chongqing Twin-Circle is located in an inland geographical area, with a relatively small amount of seafood. However, this region has a relatively high production capacity in terms of grain, vegetables, fruits, and livestock and poultry breeding. For

instance, both Sichuan Province and Chongqing Municipality are significant grain-producing areas in China, and their grain output holds an important position nationwide. In addition, the Chengdu-Chongqing region is actively developing characteristic agriculture and modern agriculture, and improving agricultural production efficiency and product quality through scientific and technological innovation and industrial upgrading.

According to the "Chengdu Statistical Yearbook 2022" and the "Chongqing Statistical Yearbook 2022", the food supply mainly consists of the four major carp species, crucian carp, mandarin fish, and crustaceans, etc. In that year, the total supply in Chengdu and Chongqing was 149,336 tons and 566,303 tons respectively. The average price of freshwater products was 10 yuan /kg and 14.25 yuan /kg respectively. Then the value of food supply was 0.0015 million yuan and 0.00807 million yuan respectively.

$$\sum VP3=PP3 \times QP3 \quad (3)$$

In the formula: VP3 represents the value of any type of aquatic product, amounting to billions of yuan; PP3 represents the output of any type of aquatic product, ; QP3 represents the unit price of any type of aquatic product, in yuan per kilogram.

3.3.2. Adjust Service Value

1. Surface water storage

The Chengdu-Chongqing Twin-City Economic Circle is rich in water resources, mainly including the Yangtze River, the Jialing River, the Minjiang River, the Tuojiang River and their tributaries. These water systems not only provide abundant surface water resources for the Chengdu-Chongqing region, but also form several important lakes and reservoirs, further enhancing the surface water storage capacity. The Chengdu-Chongqing Twin-City Economic Circle attaches great importance to water quality protection. By strengthening pollution source control and implementing water ecological restoration and other measures, it continuously improves the water quality of surface water. Meanwhile, strengthen the construction of water quality monitoring and early warning mechanisms to ensure water quality safety.

This paper calculates the surface water storage using the shadow price method, and the calculation formula is shown in Equation (4). According to the "2022 Chengdu Water Resources Bulletin" and the "2022 Chongqing Water Resources Bulletin", the total surface water resources of the two cities in 2022 were 6.939 billion cubic meters and 6.57656 billion cubic meters respectively. The unit regulation and storage price is replaced by the unit reservoir manufacturing cost. The average manufacturing costs per unit reservoir in that year were 30.932 yuan /m³ and 20.37 yuan /m³ respectively. It can be concluded that the total value of surface water regulation and storage is 214.6371 billion yuan and 1,339.6645 billion yuan respectively.

$$VR4=PR4 \times QR4 \quad (4)$$

In the formula: VR4 represents the value of surface water regulation and storage, amounting to billions of yuan; PR4 is the unit storage and regulation price, yuan per cubic meter; QR4 represents the total volume of surface water storage and regulation, in billions of cubic meters.

2. Groundwater reserve

The Chengdu-Chongqing Twin-City Economic Circle is rich in groundwater resources, which play an important role in agricultural irrigation, industrial production and domestic

water supply for residents within the region. Meanwhile, the formation and distribution of groundwater resources are also influenced by various factors such as geological structure, hydrogeological conditions, and climatic conditions.

Agricultural irrigation: In the Chengdu-Chongqing region, groundwater is widely used for agricultural irrigation, especially in areas where water resources are relatively scarce, groundwater has become an important source of irrigation water.

Industrial production: Some industrial enterprises also utilize groundwater for production activities. However, with the increasing awareness of water resource protection, the reliance of industrial water on groundwater resources is gradually decreasing.

Residents' daily life: In some remote areas or regions with incomplete water supply facilities, residents' daily water use also partially relies on groundwater.

In this paper, the shadow price method is adopted for the calculation of groundwater regulation and storage, and the calculation formula is shown in Equation (5). In 2022, the total groundwater resources in Chengdu and Chongqing were 2.99 billion cubic meters and 546.9 million cubic meters respectively. The unit regulation and storage price was replaced by the unit reservoir manufacturing cost. The average unit reservoir manufacturing cost for that year was 30.932 yuan/cubic meter and 20.37 yuan/cubic meter respectively. Thus, it can be concluded that the total value of groundwater regulation and storage is 92.4876 billion yuan and 1.114 billion yuan respectively.

$$VR5=PR5 \times QR5 \quad (5)$$

In the formula: VR5 represents the groundwater reserve value in billions of yuan; PR5 is the unit storage and regulation price, yuan per cubic meter. QR5 represents the total volume of groundwater regulation and storage, in billions of cubic meters.

3. Water quality purification

According to relevant data, the proportion of excellent water quality within the construction planning scope of the Chengdu-Chongqing Twin-City Economic Circle has reached a relatively high level. The Chengdu-Chongqing Twin-City Economic Circle has formulated and implemented policy documents such as the "Ecological and Environmental Protection Plan for the Chengdu-Chongqing Twin-City Economic Circle", clearly defining the goals and tasks of water quality purification, including the expansion of sewage treatment plants for pollution control, ecological restoration of rivers, and control of non-point source pollution. The implementation of these goals has effectively enhanced the self-purification capacity of water bodies in the region and improved the quality of the water environment.

This paper adopts the alternative cost method for calculation, and the calculation formula is shown in Equation (6). Among them, the purification value of surface water quality per unit volume is replaced by the cost of sewage treatment. According to the environmental statistics of Chengdu and Chongqing in 2022, the sewage discharge volume was 1,238.46 million cubic meters and 1,699.36 million cubic meters respectively, and the purification value of surface water quality per unit volume was 0.85 yuan /m³ and 1.3 yuan /m³ respectively. The total value of water purification was 105.3 million yuan and 220.9 million yuan respectively.

$$VR6=PR6 \times QR6 \quad (6)$$

In the formula: VR6 represents the water purification value, amounting to hundreds of millions of yuan; PR6 represents the purification value of surface water quality per unit volume, in yuan /m³. QR6 represents the sewage discharge volume, in ten thousand tons.

4. Climate regulation

The Chengdu-Chongqing region is located in the Sichuan Basin. Its precipitation is influenced by various factors such as monsoon and topography, and there are significant interannual and seasonal variations. The increase or decrease of precipitation directly affects the replenishment of surface water and groundwater, and thereby influences the total amount of water resources in the entire region. In recent years, the Chengdu-Chongqing region has also been confronted with more frequent extreme weather events, such as heavy rain and drought. Heavy rain may cause flood disasters, while drought will make the problem of water shortage even more severe. For instance, Dazhou City, located in the important connection zone of the Chengdu-Chongqing Twin-Circle, has suffered from the most severe rainstorm and flood, as well as the strongest high temperature and summer drought and other extreme weather events since 1961 when complete meteorological records began, which have had a serious impact on local water resources.

For climate regulation, this paper adopts the result reference method for calculation, and the calculation formula is shown in Equation (7). The water areas of Chengdu and Chongqing are QR7, which are 973 million square meters and 824 million square meters respectively. The climate regulation value PR7 per unit water area is replaced by the agricultural water price. According to the water supply price of water conservancy projects, the PR7 of the two cities can be obtained as 0.12 yuan/square meter and 0.17 yuan/square meter respectively. The total value of climate regulation is 116.76 million yuan and 140.8 million yuan respectively.

$$VR7=PR7 \times QR7 \quad (7)$$

In the formula: VR7 represents the climate value regulation, amounting to billions of yuan; PR7 represents the climate regulation value per unit water area, in yuan per square meter. QR7 represents the water area, in billions of square meters.

5. Flood regulation and storage

Flood regulation and storage is a complex and systematic project, aiming to enhance regional flood control and disaster reduction capabilities by establishing a complete water security guarantee system, and to ensure the safety of people's lives and property as well as the stable development of the economy and society. In terms of flood regulation and storage, the Chengdu-Chongqing Twin-City Economic Circle has proposed an overall spatial layout for water security guarantee featuring "two circles, two wings, four screens and multiple corridors".

The "Double Circles" refer to the Chongqing Metropolitan Area and the Chengdu Metropolitan Area, which are the core regions for regional flood control and disaster reduction.

The two wings: The northern wing includes northeastern Sichuan and northeastern Chongqing, while the southern wing covers areas such as Ya'an and Leshan. They are important supporting regions for flood control and disaster reduction.

The Four Screens: With the Minshan - Qionglai - Liangshan, Mica - Daba, Wuling and Dalou Mountains around the basin as important ecological barriers, they play a significant role in flood control and disaster reduction.

Multiple corridors: With the main stream of the Yangtze River and its important tributaries as corridors, the main channels for flood regulation, storage and discharge are formed.

The alternative engineering method is adopted for calculation, and the calculation formula is shown in Equation (8). Among them, the unit regulation and storage price is replaced by the average cost of reservoir manufacturing. In 2022, the reservoir capacities of Chengdu and Chongqing were 1.334 billion cubic meters and 5.19309 billion cubic meters respectively, and the average construction costs of reservoirs were 30.932 yuan per cubic meter and 20.37 yuan per cubic meter respectively. The total value of flood regulation and storage can be calculated to be 41.2633 billion yuan and 105.7832 billion yuan respectively.

$$VR8=PR8 \times QR8 \quad (8)$$

In the formula: VR8 represents the value of flood regulation and storage, amounting to hundreds of millions of yuan. PR8 is the unit storage and regulation price, yuan per cubic meter. QR8 represents the flood regulation and storage capacity, in billions of cubic meters.

3.3.3. Cultural Service Value

1. Cultural services

The integrated development of culture and tourism is another major highlight in the cultural service sector of the Chengdu-Chongqing Twin-City Economic Circle. Relying on their unique natural scenery and rich historical and cultural heritage, the two places have joined hands to build the Bashu Cultural Tourism Corridor and carefully created a series of high-quality tourism routes integrating natural beauty and humanistic charm. Meanwhile, the innovative development of cultural tourism has also provided a new source of impetus for the transformation and upgrading of the regional economy, promoting the deep integration and coordinated development of the cultural industry and the tourism industry.

This paper adopts the market value method to measure the cultural service value of the aquatic ecosystem, and the calculation formula is shown in Equation (9). According to the "Chengdu Statistical Yearbook 2022" and the "Chongqing Statistical Yearbook 2022", in 2022, the number of visitors to relevant leisure and entertainment venues in Chengdu and Chongqing was 163.79 million and 655.01 million respectively, and the average consumption at the venues was 276.9 yuan and 293.73 yuan per person respectively. The total value of cultural services was 4.5353 billion yuan and 19.2396 billion yuan respectively.

$$VP9=PP9 \times QP9 \quad (9)$$

In the formula: VP9 represents the total revenue generated by leisure and entertainment venues mainly based on water ecosystems; PP9 represents the per capita consumption price of leisure and entertainment venues, which is yuan per person. QP9 represents the average annual number of tourists, in ten thousand person-times.

3.4. Subsequent Evaluation of Value Accounting

After total calculation, the total value of water resources GEP in Chengdu in 2022 was 361.25341 billion yuan, and that in Chongqing was 1,467.1099 billion yuan. The detailed information is shown in Table 1.

Table 1. GEP value calculation of water resources in the Chengdu-Chongqing Twin-Circle

GEP value calculation of water resources in the Chengdu-Chongqing Twin-Circle						
Ecological products and services category	First-level indicator	Functional quantity	Function quantity value		Value quantity/billion yuan	
			Chengdu city	Chongqing Municipality	Chengdu city	Chongqing Municipality
Product service	domestic water	domestic water consumption	0.85 billion m ³	1.66077 billion m ³	2.865	5.813
	Industrial water use	Industrial water consumption	4.0467 billion m ³	5.0417 billion m ³	5.19236	11.26151
	food supply	fishery products	149336 t	566303 t	0.00015	0.000807
Mediation service	Surface water regulation and storage	Total amount of surface water resources	6.939billion m ³	6.57656 billion m ³	214.6371	1333.9645
	Groundwater regulation and storage	Total groundwater resources	2.99 billion m ³	0.05469 billion m ³	92.4876	1.114
	water quality purification	Quantity of wastewater effluent	1238.46 million m ³	1699.36 million m ³	0.1053	0.2209
	Climate regulation	The amount of water absorbed by evaporation on the water surface and the amount of water evaporated	0.973 billion m ³	0.824 billion m ³	0.11676	0.14008
	Flood water storage	Storage capacity	1.334 billion m ³	5.19309 billion m ³	41.2633	105.7832
Cultural services	Entertainment	Average annual number of tourists	16379 Ten thousand person-times	30000 Ten thousand person-times	4.535	8.8119

The proportion of product and service value in Chengdu is 2.23%, and that in Chongqing is 1.164%, both of which account for relatively small amounts. Among them, industrial water use accounts for the highest proportion. The reason lies in the large demand for agricultural water. As an important agricultural area in the southwest region, the Chengdu-Chongqing Twin-City Economic Circle has always had a large demand for agricultural water. Moreover, Chengdu and Chongqing, as the core cities in the region, have widely distributed farmlands and agricultural irrigation areas in their surrounding areas, which leads to agricultural water use occupying an important position in industrial water use. With the development of modern agricultural technology and the improvement of irrigation efficiency, although the water consumption per unit area has decreased, the overall demand for agricultural water still remains at a relatively high level. In recent years, the industrialization process in the Chengdu-Chongqing Twin-City Economic Circle has accelerated, and the demand for water resources in the industrial sector has significantly increased. The cooling, cleaning, processing and other links in industrial production all require a large amount of water, which has led to an increase in the proportion of industrial water. Especially in Chengdu and Chongqing, as the economic centers within the region, their industrial development is relatively rapid, and the demand for industrial water has also increased accordingly.

In terms of regulating the value of services, Chengdu accounted for 96.5%, and Chongqing even reached as high as 98.24%, both ranking first. Among them, the value of surface water storage and regulation is significantly the highest. This is mainly because the Chengdu-Chongqing Twin-City Economic Circle is located in the Sichuan Basin and has

relatively abundant water resources, especially surface water resources. This natural condition provides a good foundation for the regulation and storage of surface water. Moreover, due to the uneven distribution of water resources within the Chengdu-Chongqing Twin-City Economic Circle, but through measures such as cross-regional water diversion projects and optimal allocation of water resources, the effective utilization and sharing of water resources have been achieved. Therefore, strengthening the regulation and storage of surface water is also one of the important means to ensure regional water resource security. This explains why the value of surface water regulation and storage volume is the highest among the values of regulation services.

The proportion of cultural service value in the total value is the smallest. Chengdu City and Chongqing City account for only 1.27% and 0.596% of the total value respectively.

3.5. Presentation of Value Accounting Issues

It can be seen from Table 2 that there are differences between Chengdu City and Chongqing City in terms of domestic water use, industrial water use, total surface water resources, and total groundwater resources. For example, the total amount of surface water resources in Chengdu is 6.939 billion cubic meters, and that in Chongqing is 6.57656 billion cubic meters. The total amount of groundwater resources in Chengdu is 2.99 billion cubic meters, and that in Chongqing is 54.69 million cubic meters. This indicates that there is an imbalance in the distribution of water resources between the two places. This uneven distribution may lead to water shortages in some areas, while in others, water resources are relatively abundant but not fully utilized.

Meanwhile, water resources are also closely related to

climate change. Climate change may lead to problems such as uneven precipitation distribution, rising temperatures and increased evaporation, thereby affecting the quantity and quality of water resources. For instance, global warming may lead to the melting of glaciers and the rise of sea levels, affecting the water supply in the Chengdu-Chongqing twin-circle. Meanwhile, the increase in extreme weather events, such as heavy rain and drought, will also pose challenges to water resource management.

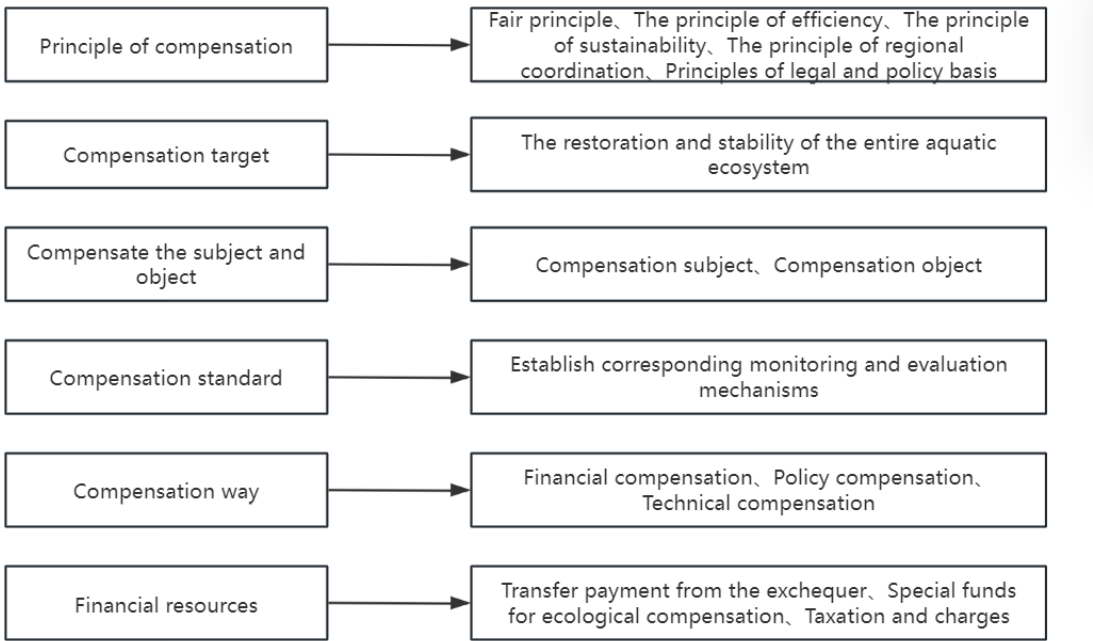
The sewage discharge volume of Chengdu City is 1,238.46 million cubic meters, and that of Chongqing City is 1,699.36 million cubic meters. However, the sewage treatment capacity of the two places is relatively limited, with values of 105.3 million yuan and 220.9 million yuan respectively, indicating that the sewage treatment capacity needs to be improved. Some rivers and lakes in the Chengdu-Chongqing region have varying degrees of water pollution problems, with water quality categories mostly classified as Class IIIV or even lower. Water environmental pollution not only affects the usability of water resources, but also threatens the ecological environment and human health.

4. Ecological Compensation Mechanism

The construction of the water resources ecological

compensation system in the Chengdu-Chongqing Twin-City Economic Circle is a complex and long-term strategic task, aiming to ensure the long-term sustainable service capacity of the water resources ecosystem in this region. This chapter will establish the framework of the ecological compensation mechanism for water resources in the Chengdu-Chongqing Twin-Circle from six major aspects: compensation principles, compensation targets, compensation subjects and objects, compensation standards, compensation methods, and sources of funds, to solve the problems reflected in Table 2, as shown in Table 2 below. Based on the research results in Chapter Three of this paper, the ecological compensation mechanism in this chapter is mainly aimed at maintaining the sustainable development of water resources ecosystem services in the Chengdu-Chongqing Twin-Circle. It focuses on three major parts: compensation subjects and objects, compensation standards, and compensation methods. Relying on the three core contents of the ecological compensation mechanism, it provides reference opinions for the construction of the water resources ecosystem in the Chengdu-Chongqing Twin-circle. To promote the sustainable utilization of regional water resources and the coordinated development of the ecological environment, thereby facilitating the sustainable utilization of regional water resources and the coordinated development of the ecological environment.

Table 2. The framework of the ecological compensation mechanism for water resources in the Chengdu-Chongqing Twin-Circle



4.1. Compensation Principle

The ecological compensation mechanism for water resources in the Chengdu-Chongqing Twin-circle should adhere to the principles of fairness, efficiency, sustainability, regional coordination, and legal and policy basis.

(1) The principle of fairness

Resource value manifestation: Ensure that users of water resources assume corresponding compensation responsibilities based on the amount of water they consume, water quality, and the degree of impact on the ecological environment, so as to fairly reflect the value of water resources.

Balance of interests: During the compensation process, the interests of water resource protectors, beneficiaries and victims should be well balanced to ensure fairness among all parties in protecting water resources and enjoying the benefits of water resources. For the beneficiaries of water resources, including agricultural irrigators, industrial water-using enterprises, urban residents, etc., the mechanism requires them to share the cost of water resource protection reasonably in accordance with the principle of "who benefits, who pays", based on their respective water resource usage, usage benefits and potential environmental impact. This can not only reflect the economic value of water resources, but also guide the beneficiaries to adopt more water-saving and environmentally

friendly production and lifestyle.

(2) Efficiency principle

Incentive mechanism: As the core link of water resource management strategies, the incentive mechanism profoundly influences the behavioral patterns and decision-making processes of water resource users through the ingenious application of economic incentive measures. These measures include but are not limited to the tiered water pricing system, water-saving incentive policies, and punitive charges for excessive water use. They aim to positively encourage users to reduce waste and adopt more water-saving and environmentally friendly measures to meet their water resource demands in the form of economic levers. Specifically, tiered water pricing encourages users to utilize water resources within a reasonable range by gradually increasing the marginal price of water consumption. Water-saving rewards directly provide economic subsidies or tax reductions to users who have taken water-saving measures and achieved remarkable results, thereby strengthening the positive feedback of their water-saving behaviors. Punitive charges for excessive water use, on the other hand, curb the excessive consumption of water resources by increasing additional costs.

Cost-benefit analysis: Cost-benefit analysis not only requires a comprehensive assessment of the direct and indirect costs required for implementing the compensation mechanism, including expenses in aspects such as fund raising, management and operation, and supervision and execution, but also needs to carefully consider the multiple benefits that this mechanism can bring. In terms of environmental benefits, analyze how the compensation mechanism promotes the protection and restoration of water resources, reduces water pollution, and improves the health of the ecosystem; In terms of economic benefits, assess its positive impact on the efficient allocation of water resources, industrial transformation and upgrading, and the transformation of the economic growth mode, etc. In terms of social benefits, attention is paid to its contributions to social equity, public health, social stability and other aspects. By comprehensively comparing costs and benefits, it is ensured that the design of the compensation mechanism not only conforms to economic rationality but also achieves the coordinated unity of the three major benefits of the environment, economy and society, providing strong support for the sustainable management of water resources.

(3) Sustainability principle

Ecological protection, as one of the core goals in the design of water resource management and compensation mechanisms, emphasizes that while promoting economic development, the protection and restoration of the natural environment must also be taken into account. A sound water resources compensation mechanism should be able to effectively motivate all stakeholders to participate in ecological protection actions. Through various means such as economic compensation, technical support and policy guidance, it should promote the virtuous cycle of the water resources ecosystem. This not only includes preventing and reducing the damage to the ecological environment during the development and utilization of water resources, such as strictly controlling pollutant emissions and implementing ecological restoration projects, but also covers the active restoration and reconstruction of the damaged ecological environment to restore the natural purification capacity of water bodies and protect biodiversity, thereby ensuring the

long-term sustainable utilization of water resources.

To achieve this goal, long-term planning is particularly important. When formulating water resource compensation policies, it is necessary to take a holistic and long-term perspective, fully consider multiple factors such as economy, society and environment, and ensure that the compensation mechanism can not only solve the current problems faced, but also adapt to the needs of future development. This requires policymakers to conduct in-depth research on the changing trends of water resources, the carrying capacity of the ecological environment, the development laws of the social economy, etc., and formulate long-term plans that are forward-looking, systematic and operational.

(4) Principle of regional coordination

The regional coordination of water resources refers to the balanced distribution and efficient utilization of water resources within a certain geographical area through reasonable planning, management and allocation, so as to meet the economic and social development needs and ecological and environmental protection requirements of different regions. In the specific area of the Chengdu-Chongqing Twin-Circle, the regional coordination of water resources is particularly important because the problem of uneven distribution of water resources in this region is rather prominent. By building inter-basin water diversion projects, such as the South-to-North Water Diversion Project, water resources can be allocated from relatively abundant areas to water-scarce areas to alleviate the problem of uneven distribution of water resources. Within the Chengdu-Chongqing Twin-Circle, although there are no large-scale inter-basin water transfer projects yet, the optimal allocation of water resources can be achieved through the allocation and joint dispatching among small watersheds within the region.

(5) Principles of legal and policy basis

Legal foundation: The establishment of a compensation mechanism must be deeply rooted in relevant national and local laws and regulations to ensure that all compensation actions comply with the legal framework and have a solid foundation of legality and compliance.

Policy alignment: To ensure the effectiveness and timeliness of the compensation mechanism, we should closely track and adapt to the policy orientation of water resource protection at both the national and local levels, keeping the compensation mechanism highly consistent with the policy goals, thereby providing a solid backing and strong support for the smooth implementation of national and local policies.

4.2. Compensation Objectives

At present, many ecological compensation mechanisms in river basins often focus solely on water quality restoration as the ultimate goal, but ignore the importance of the comprehensive improvement and long-term stability of the overall ecological environment quality of the river basin. This approach fails to fully tap into and leverage the inherent regulatory and restorative capabilities of natural ecosystems to naturally enhance the quality of the water ecological environment. At the same time, it also fails to deeply recognize the chain reaction of the continuous deterioration of the water environment caused by the decline of natural ecosystems. Therefore, it also increases the cost of water ecological environment governance and protection.

In this regard, this paper positions the ecological compensation goal of water resources in the Chengdu-

Chongqing Twin-City Economic Circle as the restoration and stability of the entire aquatic ecosystem, especially focusing on problems such as the uneven distribution of water resources and the weak sewage treatment capacity in the Chengdu-Chongqing Twin-City Economic Circle, which is reflected in the improvement and enhancement of important ecosystem services in the waters of the Chengdu-Chongqing Twin-City Economic Circle. In order to fully utilize the regulatory role of the ecosystem itself and achieve the goal of improving the water ecological environment once and for all.

4.3. Compensation for the Subject and Object

4.3.1. Compensation Subject

According to the principle of ecological compensation and Table 2, the main body of water resource compensation in the Chengdu-Chongqing Twin-Circle should be the destroyer of the ecological environment, the beneficiary of ecosystem services, or government departments that can represent the beneficiary groups, etc.

From the perspective of ecological and environmental destroyers, taking the most typical example to illustrate, the commercial concrete (i.e. commercial concrete) industry, as an important pillar of infrastructure construction, the environmental problems accompanying its production and application processes, especially the pollution of water resources, have increasingly become social and ecological challenges that cannot be ignored. These untreated or improperly disposed wastes not only directly cause profound changes in soil structure, gradually hardening and compacting it, losing its original fertility and permeability, but also seriously affect the balance of the soil ecosystem and the normal growth of crops. Farmland, as the cornerstone of the human food chain, once exposed to such pollution, its production potential will decline significantly, and it may even lead to land degradation, posing a serious threat to local agricultural productivity and food safety. What is even more serious is that these wastes may eventually flow into the Minjiang River and other river basins through natural processes such as rainwater erosion and surface runoff, causing incalculable pollution to water quality. As an important water system in the Chengdu-Chongqing region and even the upper reaches of the Yangtze River, the deterioration of the water quality of the Minjiang River will directly affect the ecological security and drinking water health of residents in the downstream areas, triggering a chain reaction, intensifying water resource shortages and water quality crises, and posing a major challenge to the sustainable development of the regional economy.

From the perspective of beneficiaries of ecological services, the extensive use of energy in high energy and water consumption industries, such as industrial and agricultural activities, has significantly increased the resource and environmental pressure on water resources in the Chengdu-Chongqing Twin-circle. The excessive consumption of water resources, the massive discharge of sewage, and the relatively low rate of water reuse have also brought about an ecological burden on water resources. These enterprises, as beneficiaries of the ecological environment, should be included in the category of ecological compensation subjects for water resources in the Chengdu-Chongqing Twin-Circle basin.

In conclusion, the main body of ecological compensation for water resources in the Chengdu-Chongqing Twin-Circle basin should be government departments at all levels. Chengdu City and Chongqing Municipality should give full

play to their main guiding and assisting responsibilities, providing financial, material and technical compensation to the two municipal governments. The governments of Chengdu and Chongqing should, within their financial capacity and in accordance with the guidance of their superior governments, provide assistance to farmers and breeders in the water resource basins of the Chengdu-Chongqing Double Circle for the transformation to green agriculture, and do a good job in the restoration and protection of the basin ecosystems. In addition, high energy-consuming and high-polluting enterprises, high water-consuming enterprises and residents within the basin should all be included in the scope of ecological compensation subjects to provide corresponding compensation for the restoration of ecosystem services in the water resources basin of the Chengdu-Chongqing Twin-Circle.

4.3.2. Compensation Object

According to the principle of ecological compensation, the compensation targets for water resources in the Chengdu-Chongqing Twin-Circle basin should be farmers who have lost land due to the construction of reservoirs, communities that have been affected by river course changes, and other ecological protection contributors, ecological damage and damage victims, ecological governance victims, and ecological damage and loss mitigated individuals. To improve the current situation of ecosystem services in the water resource basins of the Chengdu-Chongqing Twin-Chongqing Circle, it is necessary to start from the influencing factors of ecosystem services. Only with the leadership of the government and the participation of the entire population can the goal of ecological compensation be achieved. Therefore, the objects of ecological compensation present the characteristics of diversity and variability, and some even have the identity of compensation subjects.

Taking the commercial concrete industry in the Chengdu-Chongqing region as an example, as an important area in the upper reaches of the Yangtze River Economic Belt, the water resource situation in the Chengdu-Chongqing region directly affects the ecological environment and economic development of the downstream areas. Therefore, enterprises in this region, including the commercial concrete industry, bear significant responsibilities in the protection of water resources. This kind of responsibility often means that more funds and technologies need to be invested in the construction and operation of environmental protection facilities, thereby increasing the cost burden of enterprises. Moreover, the commercial concrete industry may generate pollutants such as wastewater and waste residue during the production process. The treatment of these pollutants requires professional technology and equipment, and the treatment cost is relatively high. To meet environmental protection standards, the commercial concrete industry needs to invest a large amount of funds in pollution control, which exerts certain pressure on its operating profits.

The main recipients of ecological compensation in the Chengdu-Chongqing Twin-Circle River Basin are local governments that formulate compensation policies and supervise their implementation, enterprises, farmers and residents that cooperate with government regulation and take ecological protection actions, as well as collectives or individuals whose interests have been damaged due to ecological governance.

4.4. Compensation Standards

With the development of the economy and society and the changes in the requirements for ecological and environmental protection, the compensation standards also need to be dynamically adjusted and updated in a timely manner. This requires the establishment of corresponding monitoring and evaluation mechanisms to timely grasp the changing trends of water resource protection and utilization, and provide a basis for the adjustment of compensation standards. The compensation standards should be based on scientific assessment and reasonable analysis to ensure their operability and executability. This requires that when formulating compensation standards, the actual situation and operability be fully considered to avoid situations where the standards are too high or too low, resulting in inability to implement or poor effects. In the specific implementation, the compensation standards for water resources in the Chengdu-Chongqing Twin-Circle may be comprehensively considered based on multiple aspects such as water volume, water quality, ecological protection, and water resource conservation and protection. For example, in terms of water volume compensation, different compensation amounts may be set according to different intervals of the total annual water volume. In terms of water quality compensation, the compensation standards may be determined based on the results of water quality monitoring and the degree of pollution. Meanwhile, factors such as ecological protection costs, water resource conservation and protection investment will also be taken into account to formulate comprehensive compensation standards.

4.5. Compensation Methods

4.5.1. Economic Compensation

From the perspective of government compensation, the government has set up special fiscal funds to support water resource protection, governance and water ecological restoration projects. These funds can be raised through means such as central fiscal transfer payments and local fiscal budget arrangements. Financial subsidies or rewards should be provided to enterprises and individuals who actively participate in water resource protection, water-saving renovations and pollution control to encourage their continued investment and efforts. For enterprises engaged in industries related to water resource conservation, recycling and pollution control, preferential policies such as tax reduction and exemption and tax refund will be implemented to lower their operating costs and encourage them to increase investment.

From the perspective of market compensation, efforts should be made to promote the construction of the water rights market and allow the trading of water resources' usage rights in the market. Through market mechanisms, transform water resources from inefficient utilization to efficient utilization, and achieve economic compensation at the same time. Utilize green financial tools, such as green bonds and green credits, to provide financial support for water resource protection, governance and water ecological restoration projects. These financial tools can reduce the financing cost of the project and attract more social capital investment. Establish a pollution discharge rights trading market and allow enterprises to buy and sell pollution discharge rights in the market. Through market mechanisms, enterprises can pursue economic benefits while paying more attention to the control and reduction of pollution emissions, thereby

achieving indirect protection of water resources and economic compensation.

From the perspective of social compensation, it is encouraged to make social donations and establish public welfare funds to support water resource protection, governance and water ecological restoration projects. These funds can come from multiple channels such as enterprises, individuals and social organizations.

4.5.2. Policy Compensation

The "Water Security Assurance Plan for the Chengdu-Chongqing Twin-City Economic Circle" has been successfully upgraded to a national-level plan, providing top-level design and policy support for the development and governance of water resources in the Chengdu-Chongqing Twin-City Economic Circle. This plan clearly defines five key tasks: improving the flood control and disaster reduction system in river basins, accelerating the construction of major regional water network projects, strengthening protection and restoration, enhancing digital integration, and deepening innovation collaboration. Within the Chengdu-Chongqing Twin-Circle area, relying on the natural water systems such as the Yangtze River and the Jialing River as well as the layout of water supply facilities, local water, water passing through and water transferred from outside will be allocated in a coordinated manner, and the construction of major water resources allocation projects across river basins and regions will be promoted. For instance, the construction of key water conservancy projects such as the Water Resources Allocation Project in Western Chongqing and the Water Diversion Project from the Yangtze River to the Min River aims to address engineering-induced water shortages and enhance the regional water resources allocation capacity and water supply security guarantee level. The Sichuan-Chongqing River Chief Joint Promotion Office was also established to deepen the effective interaction between the river chief systems of Sichuan and Chongqing, and to strengthen the joint governance, investigation, and supervision of cross-boundary rivers. At the same time, integrate and connect the information platform of the river chief system for cross-border rivers, establish an information sharing mechanism for cross-border rivers, and regularly share monitoring information such as water quality and quantity, and environmental risk and hidden danger points of cross-border rivers.

4.5.3. Technical Compensation

Relying on digital, networked and intelligent technologies, the Chengdu-Chongqing Twin Circles are comprehensively promoting the construction of a smart water conservancy system. This includes building digital twin water networks, digital twin river basins and digital twin water conservancy projects to achieve precise management and decision-making of water conservancy projects. Through intelligent simulation and precise decision-making, the efficiency of water resource dispatching and management can be enhanced to ensure the rational allocation and efficient utilization of water resources. Build an intelligent application system covering water conservancy projects, the river chief system, the management of the Three Gorges Reservoir Area, soil and water conservation, rural water supply, water law enforcement, and water conservancy government services. These intelligent applications utilize advanced technologies such as big data, cloud computing, and the Internet of Things to achieve intelligent management and services for water conservancy business. The Chengdu-Chongqing Twin Circles are

accelerating the construction of scientific and technological innovation platforms, such as the Chengdu-Chongqing Comprehensive Science Center and the Western Science City. These platforms provide strong support for water conservancy science and technology innovation, promoting the continuous progress and application of water conservancy science and technology.

At the same time, strengthen scientific and technological innovation cooperation with other fields, and promote the integration and innovative development of science and technology across disciplines and fields. By using advanced technologies such as remote sensing and unmanned aerial vehicles, a comprehensive monitoring and assessment of the water ecosystem in the Chengdu-Chongqing Twin-circle is conducted. To understand the health status and changing trends of water ecosystems and provide scientific basis for ecological protection and restoration.

4.6. Sources of Funds

To ensure the sufficiency and sustainability of ecological compensation funds for water resources in the Chengdu-Chongqing Twin-Circle basin, it is suggested to establish diversified channels for raising funds and obtain ecological compensation funds through various means such as fiscal transfer payments, special funds for ecological compensation, as well as taxes and fees.

The development, governance and maintenance projects of water resources in the Chengdu-Chongqing Twin-Circle often have high public welfare and strategic significance. Therefore, the central and local governments will provide financial support in the form of fiscal appropriations. These funds are usually used in key areas such as the construction of major water conservancy projects, the establishment of flood control and disaster reduction systems, and the restoration and protection of water ecosystems. The government will also establish special funds, such as the Development Fund for the Chengdu-Chongqing Twin-City Economic Circle, to support the construction of water conservancy infrastructure and water resource management within the region. These funds are usually jointly established by multiple government departments, state-owned enterprises and social capital, aiming to promote the efficient utilization and sustainable development of regional water resources through the leverage of funds.

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