

Analysis of the Development and Utilization of Surface Water Resources of the Yellow River in Henan Province

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Abstract: The development and utilization of surface water resources of the Yellow River and its impact on the industrial development of the receiving area were explored through the statistical analysis of data related to water resources in the Yellow Diversion Receiving Area of Henan Province from 2003 to 2022. The results of the study show that the Yellow River water resources have played a crucial role in supporting the socio-economic development of the Yellow Diversion Receiving Area in Henan Province, especially in the agricultural sector, where the contribution is particularly significant. During this period, 79.03% of the total Yellow River water introduced into the Yellow River receiving area in Henan Province has been applied to agricultural production, and the amount of Yellow River water diverted has accounted for 31.46% of the agricultural water consumption. However, in recent years, with the introduction of other water sources such as the South-to-North Water Diversion, the importance of the Yellow River's water resources has relatively declined. Data show that Henan Province will only use 45.44% of the Yellow River's water consumption target in 2022, down to 2.543 billion cubic meters in 2022 compared to the peak of 5.386 billion cubic meters of diverted Yellow River water in 2012. At the same time, the proportion of water diverted from the Yellow River in the total water consumption of the receiving area has also dropped from 31.03% in 2011 to 15.80%.

Keywords: Henan Yellow River Diversion Reception Area; Yellow River Surface Water Resources; Water Resource Utilization

1. Introduction

Over the past three decades, the amount of incoming water to the Yellow River Basin has decreased significantly, and water shortage has become a key factor restricting the ecological protection and high-quality development of the basin [1]. In September 2019, at a symposium on ecological protection and high-quality development of the Yellow River Basin held in Zhengzhou, it was proposed to 'take water resources as the biggest rigid constraint, and rationally plan the development of population, cities and industries', and to 'promote a change in the way water is used from roughness to conservation and intensive use of water' as the overall objectives [2].

The per capita water resources in Henan Province is only 20% of the national average, making it one of the most water-poor provinces in China [3]. The Yellow River, as the largest inbound water resource of Henan Province, bears the water supply of 14 prefecture-level cities including Zhengzhou, and is a key resource to support the socio-economic development of Henan Province [4]. Therefore, fully utilizing the Yellow River water resources is of great significance in solving the bottleneck problem of water resources along the Yellow River and promoting the synergistic development of economy and ecology in Henan Province [5]. The statistical analysis of the development and utilization of Yellow River surface water resources in Henan Province from 2003 to 2022 reveals its contribution to the industrial development of Henan's Yellow River Diversion Receiving Zone. Such analysis is an important reference value for guiding the future economic and social development planning of the Yellow River diversion and

receiving area.

2. Research Overview

2.1 Overview of the Study Area

The Yellow Diversion Receiving Area in Henan Province covers 13 prefecture-level cities, including Zhengzhou, Kaifeng, Luoyang, Pingdingshan, Anyang, Xinxiang, Jiaozuo, Puyang, Xuchang, Sanmenxia, Shangqiu, Zhoukou, and Jiyuan, forming a coverage of the northern, western, and most of the eastern parts of Henan Province [4]. It is worth noting that Hebi City has not been included in this study because it has not been given the target of drawing water from the Yellow River. The specific object of this study is the Yellow River surface water diversion receiving area composed of the above 13 prefecture-level cities.

2.2 Overview of Yellow River Abstraction Control Indicators in Henan

In September 1987, the Notice on the Distribution Plan Report of Available Water Supply for the Yellow River was issued. According to the spirit of the Circular, under the principle of following the principle of water conservation and co-ordination, it was expected that before the implementation of the South-to-North Water Diversion Project, the annual allocation of the runoff volume of the Yellow River for the provinces along the Yellow River would be 37 billion cubic meters, of which the water-consumption target for the Yellow River mainstem and its tributaries in Henan Province would be 5.54 billion cubic meters [6].

In order to further implement the Yellow River water resource utilization targets allocated by the State to Henan Province, in June 2009, the People's Government of Henan Province issued the Circular of the People's Government of Henan Province on the Approval of the Detailed Plan for the Control Targets of the Total Quantity of Yellow River Water Abstraction Permits in Henan Province. According to the Circular, the total water consumption index of the main and tributary streams of the Yellow River obtained by Henan Province is 5.54 billion cubic meters, which is specifically allocated as follows: the water consumption index of the main stream of the Yellow River is 3.567 billion cubic meters,

and that of the tributary streams of the Yellow River is 1.973 billion cubic meters [7]. This move is aimed at managing the use of water resources of the Yellow River in a more refined way and ensuring the rational allocation and efficient utilization of water resources.

2.3 Data Sources

The water resources data of the Yellow River used in this paper come from the Yellow River Water Resources Bulletin, while the water resources information involving the Yellow Diversion Reception Area of Henan Province comes from the Water Resources Bulletin of Henan Province, water resources bulletins of the relevant prefectures and cities, and statistical yearbooks, and the statistical time period for all the data is standardized as from 2003 to 2022.

3. Analysis of the Development and Utilization of Surface Water Resources of the Yellow River in Henan Province

3.1 Analysis of the Development Status of Yellow River Surface Water Resources in Henan

In the process of formulating the annual water consumption index of the Yellow River, it is also necessary to follow the principle of "increasing abundance and decreasing wither, storing abundance to make up for dryness", and consider the annual fluctuation of the incoming water from the main stream of the Yellow River. Specific steps include: firstly, analyze the long-term runoff prediction of the current year to determine the annual natural runoff of Huayuankou Station; then, combine the long-term runoff, reservoir storage and water use plan along the Yellow River, etc., and determine the total annual water consumption according to the "87" water distribution program and related planning; finally, determine the annual water consumption according to the distribution ratio of each province (region); and finally, determine the annual water consumption of each province (region) according to the distribution ratio of each province (region). Finally, according to the allocation ratio of each province (region), the allocation index of the Yellow River's available water consumption will be determined [1,8].

The annual water consumption targets and actual water consumption in Henan Province from 2003 to 2022 are shown in Table 1, and the utilization of the annual water consumption targets is displayed in Figure 1.

Table 1. Annual Water Consumption of the Yellow River in Henan Province (Unit: 10^9m^3)

particular year	Actual water consumption of the Yellow River in Henan	Annual Water Consumption Indicators for Henan and Yellow River	Remaining indicators	Percentage of use
2003	28.25	42.38	14.13	66.66%
2004	26.07	48.97	22.9	53.24%
2005	29.32	51.58	22.26	56.84%
2006	37.77	54.64	16.87	69.13%
2007	33.64	51.1	17.46	65.83%
2008	39.43	52.54	13.11	75.05%
2009	43.36	52.01	8.65	83.37%
2010	44.1	53.19	9.09	82.91%
2011	51.95	53.6	1.65	96.92%
2012	53.86	56.77	2.91	94.87%
2013	53.23	55.17	1.94	96.48%
2014	46.78	50.83	4.05	92.03%
2015	44.31	49.84	5.53	88.90%
2016	43.21	46.86	3.65	92.21%
2017	49.72	50.8	1.08	97.87%
2018	44.72	55.83	11.11	80.10%
2019	53.34	58.6	5.26	91.02%
2020	49.76	58.6	8.84	84.91%
2021	39.21	58.6	19.39	66.91%
2022	25.43	55.96	30.53	45.44%
average	41.87	52.89	11.02	79.03%

According to the data in Table 1, the actual water consumption of the Yellow River in Henan Province between 2003 and 2022 has never exceeded the allocated water consumption targets. The average value of the water consumption target during this period was 5.289 billion cubic meters, while the average value of the actual water consumption was 4.187 billion cubic meters, meaning that 79.03% of the water consumption target was used on average, with an average remaining target of 1.102 billion cubic meters. Of these, actual water consumption reaches its highest point in 2012 at 5,386 million cubic meters, while it drops to its lowest point in 2022 at 2,543 million cubic meters. In terms of the proportion of water consumption indicators used, the maximum value of 97.87% in recent years was reached in 2017, with a remaining indicator of only 108 million cubic meters; in contrast, the proportion of water consumption indicators used in 2022 fell to 45.44%, with a

remaining indicator of 3,053 million cubic meters.

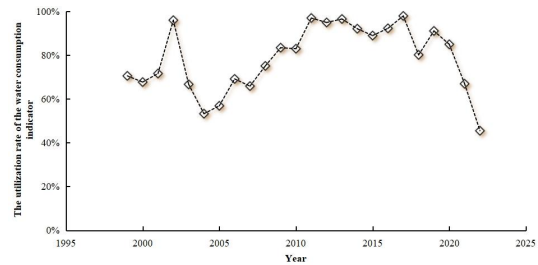


Figure 1. Henan Yellow River Allocation of Water Consumption Indicator Usage

Figure 1 demonstrates the trend of water consumption indicator utilization in the Yellow River in Henan Province from 2003 to 2022. From the Figure 1, it can be seen that the utilization rate of the water consumption indicator increased from 66.66% in 2003 after experiencing fluctuations, and then steadily rebounded to 96.92% in 2011. Thereafter, the utilization rate continued to stabilize in the range of 80% to 90% until 2020, when it began to show a downward trend, and further dropped to 45.44% by 2022.

3.2 Analysis of the Utilization Status of Yellow River Surface Water Resources in Henan

There is a difference between the definition of surface water consumption in the Yellow River Water Resources Bulletin and the provisions of the Water Resources Bulletin Preparation Procedure (GB/T23598-2009) [8]. Surface water consumption as defined in the former refers to the amount of surface water withdrawn after deducting the amount of water returned to the Yellow River channel, while the latter defines water consumption as the amount of water that cannot be returned to surface water bodies or underground saturated aquifers due to consumption by various means in the process of water transmission and use [9]. In view of the fact that the Yellow River in Henan Province is mostly a hanging river, and it is almost impossible for water resources of the Yellow River used outside the beach area to return to the river, all water diversions outside the beach area are usually regarded as water consumption [10]. For the Yellow River receiving area, the surface water consumption of each province in the Yellow River Water Resources Bulletin is the amount of water supplied by the Yellow River. The specific situation of Yellow River surface water

development and utilization in Henan Province from 2003 to 2022 is shown in Table 2.

Table 2. Utilization Status of Diverted Yellow Water in Henan Province by Industries (Unit: 10⁹m³)

Year	Agriculture			Industry			Integrated urban and rural living environment			Sum		
	A	B	C (%)	A	B	C (%)	A	B	C (%)	A	B	C (%)
2003	87.22	21.98	25.20	28.80	3.73	12.95	24.31	2.54	10.45	140.33	28.25	20.13
2004	90.66	20.36	22.46	27.54	3.39	12.31	25.64	2.32	9.05	143.84	26.07	18.12
2005	89.57	22.26	24.85	31.91	4.16	13.04	26.78	2.90	10.83	148.26	29.32	19.78
2006	104.23	29.86	28.65	34.36	4.90	14.26	27.54	3.01	10.93	166.12	37.77	22.74
2007	91.30	24.94	27.32	36.62	5.42	14.80	27.77	3.28	11.81	155.69	33.64	21.61
2008	97.70	28.48	29.15	38.04	7.34	19.29	32.02	3.61	11.28	167.76	39.43	23.50
2009	101.16	31.44	31.08	39.69	8.26	20.81	31.31	3.66	11.69	172.17	43.36	25.18
2010	90.87	29.57	32.54	41.29	9.35	22.64	32.34	5.18	16.02	164.51	44.10	26.81
2011	86.77	35.72	41.16	43.44	10.21	23.51	37.22	6.02	16.17	167.43	51.95	31.03
2012	90.87	34.51	37.98	47.46	8.98	18.92	36.25	10.37	28.61	174.57	53.86	30.85
2013	99.02	33.89	34.23	46.13	8.90	19.29	33.30	10.44	31.35	178.45	53.23	29.83
2014	81.63	29.98	36.73	41.36	7.74	18.71	32.44	9.06	27.93	155.43	46.78	30.10
2015	87.05	28.74	33.01	40.24	7.36	18.29	37.21	8.21	22.06	164.51	44.31	26.94
2016	91.08	28.86	31.69	38.79	6.78	17.48	38.31	7.57	19.76	168.18	43.21	25.69
2017	90.39	31.33	34.66	39.40	7.02	17.82	44.55	11.37	25.52	174.34	49.72	28.52
2018	86.37	29.14	33.74	38.93	6.90	17.72	46.84	8.68	18.53	172.14	44.72	25.98
2019	87.62	37.17	42.42	34.23	6.21	18.14	52.75	9.96	18.88	174.59	53.34	30.55
2020	85.62	30.87	36.06	26.54	5.10	19.21	57.90	13.79	23.82	170.06	49.76	29.26
2021	80.93	22.93	28.33	20.61	3.90	18.92	60.23	12.38	20.55	161.77	39.21	24.24
2022	90.06	16.10	17.88	16.63	2.76	16.60	54.26	6.57	12.11	160.94	25.43	15.80
average	90.51	28.41	31.46	35.60	6.42	17.74	37.95	7.05	17.87	164.05	41.87	25.33

Note: A is water consumption, B is quantity of water diverted from the Yellow River, C is the proportion of water diverted from the Yellow River.

According to the data in Table 2, the total amount of water diverted from the Yellow River in the Yellow River Diversion Receiving Area of Henan Province will be 4.187 billion cubic meters on average during the period from 2003 to 2022. Among them, agricultural water consumption is 2.841 billion cubic meters, accounting for 67.85% of the total amount of water diverted to the Yellow River, which is the largest area of water consumption; followed by urban and rural living comprehensive water consumption, which is 705 million cubic meters, accounting for 16.84%; and industrial water consumption is 642 million cubic meters, accounting for 15.33%.

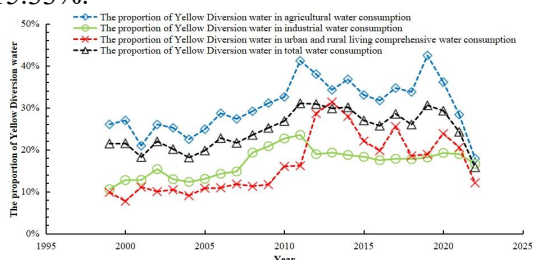


Figure 2. Proportion of Yellow Water Diversion in Each Sector in Henan's Yellow Water Diversion Receiving Area

As shown in Figure 2, the Yellow River water resources play a crucial role in the development of the Yellow Diversion Reception Area in Henan Province. Between 2003 and 2022, the average proportion of Yellow Diversion water in total water consumption in Henan Province is 25.33%. Among the water consumption of various sectors, the average proportion of agricultural, urban and rural living environment integrated and industrial water consumption is 31.46%, 17.87% and 17.74%, respectively. The average proportion of Yellow Diversion water in total water consumption in Henan Province is 25.33%.

In terms of the inter-annual trend, the proportion of water diverted from the Yellow River in Henan Province to the total water consumption shows an upward and then downward trend. This ratio reached a maximum of 31.03% in 2011 and will drop to a minimum of 15.80% in 2022. The average value of this ratio was 19.34% between 2003 and 2005, and rose to 28.69% between 2010 and 2020. In the last two years, this ratio has started to fall and further drops to 15.80% in

2022.

In agricultural water use, the share of water diverted from the Yellow River shows the same trend of increasing and then decreasing. In 2019, the share reaches a high of 42.42%, but falls to a low of 17.88% in 2022. Between 2003 and 2005, the average share was 24.15%, while between 2010 and 2020, it rose to 35.83%. In the last two years, the share declined again, to 17.88% in 2022.

The proportion of water diverted from the Yellow River in industrial water use shows an overall upward trend, reaching a maximum of 23.51% in 2011, while the lowest point was in 1999, at 10.58%. Between 2003 and 2007, the average proportion was 13.57%, and after 2007 the average proportion rose to 19.16%.

The proportion of water diverted to the Yellow River in the combined urban and rural living environment has also been on an overall upward trend, reaching a high of 31.35% in 2013 and a low of 7.72% in 2000. Between 2003 and 2009, the average proportion was 10.91%, and then rose to 22.65% after 2012, although in 2022 it will be only 12.11%.

4. Conclusions and Recommendations

(1) In recent years, the use of water consumption indicators in the Yellow River in Henan Province has shown a trend of increasing and then decreasing. Between 2011 and 2020, the proportion of water consumption indicators used remained between 80% and 90%. However, since 2020, due to the impact of the Xin Guan epidemic and other factors, the proportion of water consumption indicators used began to decline, and by 2022 it had dropped to 45.44%.

(2) The application of Yellow River water resources in the Yellow River Diversion Reception Area of Henan Province mainly focuses on agriculture, which accounts for 67.85% of the total amount of water diverted from the Yellow River from 2003 to 2022, becoming the most important area of water use, followed by urban and rural living environment water use, which accounts for 16.84%, and industrial water use, which accounts for 15.33%. In 2022 alone, the proportion of water diverted from agriculture and industry in the total amount of water diverted from the Yellow River will decrease to 63.31% and 10.85%, respectively, while the proportion of water used for integrated urban

and rural living environment will increase to 25.84%.

(3) The Yellow River water resources have played an important role in the development of the Yellow Diversion Receiving Area in Henan Province, but the status of the Yellow River water resources has declined in recent years with the implementation of the South-to-North Water Diversion Project. From 2003 to 2011, the proportion of water diverted from the Yellow River in the total water consumption of Henan Province increased from 20.13% to 31.03%, and then gradually declined to 15.80% by 2022. Taking the agricultural sector where the Yellow River water resources are most widely used as an example, from 2003 to 2011, the proportion of water diverted from the Yellow River in agricultural water consumption rose from 25.20% to 41.16%, and then declined year by year to 17.88% in 2022.

(4) In view of the above, it is recommended that the Yellow River receiving area in Henan Province should accelerate the implementation of the "four water and four fixed" policy, i.e., fixing the city with water, fixing the land with water, fixing the people with water, and fixing the production with water, and rationally deploy and utilize the water resources of the Yellow River, so as to guarantee the security of water supply for the region's urban and rural areas, improve the ecological environment of the region, and push forward the high-quality economic and social development of the region, thereby better serve the national strategy of ecological protection and high-quality development of the Yellow River basin.

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