

# Analysis of the Influence of Water Diversion from the Main Stream of the Yellow River in the Central Yellow River Diversion Project

Li Juan<sup>1,\*</sup>, Zhu Jianwen<sup>1,\*</sup>

<sup>1</sup>Yellow River Diversion Project Construction Management Co., Ltd of Central Shanxi, Taiyuan City, Shanxi Province, 030000, China

\*Corresponding author: 459680874@qq.com

**Abstract:** The water source project of the Yellow River Diversion Project (Hereafter referred to as YRDP) in the central part of Shanxi Province is located in the hinterland of the Loess Plateau, close to the Yellow River, where the natural ecological environment is fragile. Taking the water diversion for the construction of the water source project of the YRDP in the central part of Shanxi Province as an example, this paper analyzes the influence of the water diversion project on the water resources of the Yellow River region, the influence on the third party, and the influence on the regional water ecology. It is concluded that the water diversion has a subtle influence on the downstream Tianqiao hydropower station and regional water resources, has little influence on the assimilative capacity of the functional area of the water body, and has a small influence on the hydropower station and its downstream aquatic organisms. In addition, it will play a role in protecting the regional water ecological balance and supplementing and conserving the groundwater in the water receiving area, reduce the amount of groundwater over-extraction in the basin, and improve the water resources and water environment in the water receiving area, so as to promote harmony between humans and the natural environment, and enhance the ecological benefits of operating the water conservancy project.

**Keywords:** water resources, runoff, water-receiving area, aquatic organisms

## 1. The state of water resources

### 1.1. Total water resources in Yellow River Basin of Shanxi Province

According to the "Second Water Resource Evaluation of Shanxi Province" <sup>[1,2]</sup>, the total water resources in the Yellow River Basin of Shanxi Province is 7.529 billion m<sup>3</sup>, of which the river runoff is 5.090 billion m<sup>3</sup>, accounting for 68% of the total water resources. After the completion of the Yellow River Diversion Project of Central Shanxi, the water diversion will be 305 million m<sup>3</sup>.

### 1.2. The state of water resources in the water-receiving area

The water resources quantity in the water-receiving area is based on "the Second Water Resources Assessment of Xinzhou City", "the Second Water Resources Assessment of Luliang City", "the Second Water Resources Assessment of Linfen City", and "the Second Water Resources Assessment of Jinzhong City". The annual mean total volume of water resources in the water-receiving area is 1.318 billion m<sup>3</sup>, of which the volume of surface water resources is 771 million m<sup>3</sup>, the volume of groundwater resources is 867 million m<sup>3</sup>, and the repetitively calculated amount of surface water and groundwater is 320 million m<sup>3</sup>. The annual mean total volume of water resources available in the water-receiving area is 556 million m<sup>3</sup>, of which the volume of surface water resources available is 252 million m<sup>3</sup>, and the volume of groundwater resources available is 303 million m<sup>3</sup> (with the repetitively calculated amount with surface water deducted), with a utilization rate of 42.1%.

## 2. Influence on regional water resources

### 2.1. Influence on regional water resources

According to the "Comprehensive Plan for Yellow River Basin Water Resources"<sup>[3,4]</sup> compiled by the Yellow River Conservancy Commission, Shanxi Province's water resources allocation amounted to 6.443 billion m<sup>3</sup> after the east-central route of the South-North Water Transfer Project was put into use and before the first phase of the western route was put into use, of which the volume of surface water is 4.167 billion m<sup>3</sup>, the volume of groundwater is 2.111 billion m<sup>3</sup>, the volume of other water is 165 million m<sup>3</sup>; the volume of Yellow River surface water consumption is 4.022 billion m<sup>3</sup>.

The total volume of water diversion from the Yellow River Basin in Shanxi Province in 2016 is 5.35 billion m<sup>3</sup>, of which the volume of surface water is 3.28 billion m<sup>3</sup>, and the Yellow River surface water consumption is 2.879 billion m<sup>3</sup>. The designed water diversion volume of the Yellow River Diversion Project in the central part of Shanxi Province is 305 million m<sup>3</sup>, which meets the water distribution requirements in the Water Allocation Scheme in 1987 and the "Comprehensive Plan for Yellow River Basin Water Resources". From the perspective of water volume, water diversion from the Yellow River is completely guaranteed and has no major influence on regional water resources.

### 2.2. Influence on runoff in the water diversion section

*Table 1: The proportion of water diversion of the Central Yellow River Diversion Project to the intake flow of Tianqiao Hydropower Station in 50% of the years (Unit:%)*

Month/ Day	Jan	Feb	Mar	Apr	May	June	July	Oct	Nov	Dec
1	0.61	1.06	4.09	0.62	4.54	3.97	6.23	0.43	2.75	2.70
2	0.64	1.22	4.84	0.87	5.31	5.07	6.51	0.48	2.74	2.87
3	0.55	0.99	4.38	1.11	4.71	5.66	3.87	0.53	3.43	2.74
4	0.65	0.94	4.56	1.80	4.98	5.62	4.57	0.61	3.98	3.12
5	0.75	0.85	4.59	3.12	6.11	4.65	5.47	0.61	5.31	2.72
6	0.72	0.85	5.35	2.78	6.04	5.17	4.67	0.74	5.02	3.39
7	0.67	1.22	4.32	2.64	6.13	5.07	4.39	0.95	5.36	3.30
8	0.61	1.04	5.62	2.62	6.76	5.75	4.33	1.13	5.31	3.18
9	0.66	0.81	5.00	2.71	10.40	6.14	5.00	0.96	5.31	4.81
10	0.74	0.69	4.65	2.61	12.29	6.54	5.64	1.16	5.22	5.72
11	0.85	0.74	2.16	2.42	11.51	6.03	7.64	1.11	5.06	5.39
12	0.73	0.71	2.21	2.31	12.63	6.91	4.40	1.06	4.87	4.41
13	0.73	0.75	2.13	2.17	11.66	5.92	2.22	1.19	5.45	3.47
14	0.75	0.59	2.14	2.38	10.76	6.37	9.41	1.18	6.62	3.04
15	0.69	0.71	2.16	2.69	12.29	6.44	7.86	1.36	6.49	3.32
16	0.70	0.64	1.82	2.69	5.40	4.67	10.31	1.60	11.16	0.96
17	0.67	0.68	1.69	2.64	5.81	5.83	8.35	1.45	5.00	1.04
18	0.65	0.57	1.62	2.20	6.94	6.03	1.19	1.38	4.22	1.22
19	0.79	0.57	1.67	2.38	7.55	8.13	0.93	1.34	4.36	1.22
20	0.72	0.51	1.55	2.95	9.94	8.32	1.18	1.63	4.97	0.83
21	0.71	0.52	1.48	2.49	19.52	11.16	2.09	1.27	4.02	0.76
22	0.65	0.55	1.41	2.66	18.31	12.52	3.42	1.50	4.77	0.67
23	0.66	0.60	1.51	2.78	21.67	22.39	3.46	1.65	3.94	0.62
24	0.72	0.58	1.35	2.78	17.50	22.89	5.06	2.06	2.66	0.59
25	0.73	0.58	1.50	2.39	12.05	7.56	5.64	1.92	2.77	0.63
26	0.69	0.64	1.19	4.06	13.73	13.72	7.64	1.32	3.22	0.67
27	0.74	0.57	1.11	4.01	6.40	10.51	4.40	1.33	3.19	0.65
28	0.77	0.64	1.03	4.03	4.27	5.78	2.22	1.26	3.08	0.61
29	0.88	1.04	0.98	4.06	4.09	6.93	9.41	1.48	3.27	0.67
30	1.18	0.81	0.82	4.05	3.29	7.35	4.33	1.15	3.29	0.70
31	1.14	0.69	0.75	2.95	4.05	8.13	5.00	1.37	2.77	0.64

The influence on the runoff of the water diversion section<sup>[5]</sup> is analyzed. The water intake of the project is located in the reservoir area of the Tianqiao hydropower station, between Fugu and Tongguan hydrological station on the Yellow River. The designed volume of annual water diversion from the

Yellow River is 305 million m<sup>3</sup>.

According to the measured data on the runoff of the Fugu Station from 1986 to 2015, 50% of the years are selected as typical years for analysis of the daily flow. The proportion of the daily average diversion flow of the project to the daily average inflow of Tianqiao Hydropower Station in 50% of the years is shown in Table 1.

Since the water intake is controlled to not divert water when the flow rate is less than 180m<sup>3</sup>/s, and to restrict the water diversion when the flow rate is 180~240m<sup>3</sup>/s. Therefore, the water diversion of this project will not affect the ecological flow of the Yellow River during the critical period. In summary, the water diversion of the project has a certain influence on the hydrological situation of the water diversion section.

### 2.3. Influence on Tianqiao Hydropower Station

The influence on Tianqiao Hydropower Station<sup>[6]</sup> is analyzed. The foregoing analysis shows that the average daily diversion flow of the project in 50% of the years accounts for a maximum of 22.89% of the average daily inflow of Tianqiao Hydropower Station, which has a certain effect on Tianqiao Hydropower Station.

According to the analysis of the measured runoff and the actual water consumption for the power generation of the hydropower station in 50% of the years, the power generation impact rate is calculated by the product of the proportion of the designed water diversion to the reservoir water and the water utilization coefficient. The estimated value of the annual power generation impact rate of different-frequency incoming water is shown in Table 2.

Table 2 shows that the annual average power generation impact rate is 1.17%, and the annual average power generation of Tianqiao Hydropower Station is about 600 million kW·h. It is estimated that after the completion of the project, the power generation of Tianqiao Hydropower Station will be reduced by about 7.04 million kw·h. Therefore, it has little effect on the annual average power generation.

Table 2: Estimated value of annual power generation effect rate of different-frequency incoming water

Guaranteed inflow rates (%)	Designed water inflow(billion m <sup>3</sup> )	The proportion of designed water diversion volume to water inflow (%)	Water utilization ratio (%)	Power generation effect rate (%)
10	32.31	0.94	50	0.47
25	25.68	1.19	55	0.65
50	20.46	1.49	60	0.89
75	15.85	1.92	75	1.44
95	10.77	2.83	85	2.41
Mean	21.77	1.92	85	1.17

### 2.4. Influence on water-receiving area

The Yellow River Diversion Project in central Shanxi has effectively alleviated the industrial, agricultural, and urban domestic use of water in 4 cities and 16 counties (cities/districts), including Baode County in Xinzhou City, Xing County, Lin County, and Lishi District, Liulin County, Zhongyang County, Xiaoyi City, Fenyang City, Jiaokou County, Shilou County in Lvliang City, Xi County, Fenxi County, Pu County, and Daning County in Linfen City, and Jiexiu City and Lingshi County in Jinzhong City.

This project can adjust the water supply structure, alleviate the over-exploitation of the groundwater in the water-receiving area, and play a role in improving the water balance in the protection area, and supplementing and conserving groundwater.

### 2.5. Influence on the function of water bodies

The water intake of the Yellow River is located in the Yellow River Tianqiao Agricultural Water Area in the secondary functional area of the main stream of the Yellow River, with the current water quality of Class II and the target water quality of Class III.

The water diversion of the project will reduce the amount of water in the reservoir area of Tianqiao Hydropower Station, which will affect the assimilative capacity and water quality of the corresponding water body. However, the water diversion flow (23.62m<sup>3</sup>/s) of the project only accounts for 4.5% of the annual average flow, which will not cause changes in the water resources conditions of the surrounding water function areas and further reduce the water environment carrying level of the water area. Therefore, the water diversion of the project has a small influence on the assimilative capacity of the water function area in the water diversion section, and the water function of the Tianqiao Agricultural Water Area where the intake is located. The water transfer project uses a tunnel to pass through the water function zone, so it has little influence on the water function zone.

### 3. Influence on the third parties

The water intake of the project is located in the section from Fugu to Tongguan. The drainage area of the Yellow River Fugu Station is 404,000 km<sup>2</sup>, the drainage area of Tongguan Station is 680,000 km<sup>2</sup>, and the drainage area of Sanmenxia Station is 688,000 km<sup>2</sup>. According to the measurement results of runoff of the Yellow River Fugu and Sanmenxia stations (1956~2000), the annual average measured runoff in the section from Fugu to Sanmenxia is 12.849 billion m<sup>3</sup>. Because the area of the section from Tongguan to Sanmenxia interval is only 2.8% of the section from Fugu to Sanmenxia, the average measured runoff in the section from Fugu to Tongguan is adopted.

The main water diversion projects in Shanxi Province from the water intake of the project to the Tongguan section include the Yumenkou water lifting project, and electric pumping stations in Huilong, Yuanshang, Yangfan, Jiamakou, Zuncun, Fenglingdu, etc. The total annual water diversion is 464 million m<sup>3</sup>.

The main water diversion project in Shaanxi Province is the Yan'an Yellow River Diversion Project, which starts in Wangjiaqu Village, Yanshuiguan Town, Yanchuan County, on the bank of the Yellow River, and ends in Yan'an Economic and Technological Development Zone. According to the "Report on Environmental Influence of the Yellow River Diversion Project in Yan'an" compiled by the Shaanxi Hydropower Survey and Design Institute in November 2013, the annual water intake from the Yellow River is 90 million m<sup>3</sup> in 2020, the design level year.

Table 3: Statistics of Water Diversion Projects in the Reach from Fugu to Tongguan (Unit: ten thousand m<sup>3</sup>)

Administrative division	Project	Location of intakes	Water conversion in 2016	Approved water volume
Shanxi Province	Yumenkou Water Lifting Project	Hejin	18103	18500
	Huilong Electric Pumping Station	Linyi County	1317	2600
	Yuanshang Electric Pumping Station	Linyi County	2013	2400
	Yangfan Electric Pumping Station	Linyi County	1522	2200
	Jiamakou Electric Pumping Station	Linyi County	12408	18000
	Zuncun Electric Pumping Station	Yongji County	10605	14495
	Fenglingdu Electric Pumping Station	Ruicheng	462	1000
	<b>Total</b>			<b>46430</b>
Shaanxi Province	Yan'an Yellow River Diversion Project	Entrance at Yanhe River	8977	
<b>Total</b>			<b>55407</b>	<b>59195</b>

The annual Yellow River water intake in Shanxi and Shaanxi provinces totals 554 million m<sup>3</sup>, as shown in Table 3, which is much smaller than the measured runoff in the section, accounting for only 4.3% of the runoff in the section. Therefore, the water diversion of this project has little influence on the downstream water users of the intake.

#### 4. Influence on regional water ecology

##### 4.1. Influence on aquatic organisms during construction

There are few fish species and no migratory fish found in the river channel where the project is located. The impact of construction on aquatic organisms is mainly generated when the inverted siphon and aqueduct are constructed across the river. The sediment generated by the construction will increase the suspended matter in the water, thus affecting the water quality and the reproduction and activities of aquatic organisms. The construction of this project has few constructions crossing river sections and therefore has a subtle influence on regional aquatic organisms.

##### 4.2. Influence on aquatic organisms during operation

The intake of the project is located in the reservoir area of Tianqiao Hydropower Station, and the sedimentation elevation at the intake is 819.0~829.0m. The water diversion method of the water intake tower is pressureless water diversion, with a designed water diversion flow rate of 23.62m<sup>3</sup>/s. It consists of a water approach channel section, a contraction section, and a tower section, all located on the bedrock. The elevation of the bottom of the inlet passage is 826.0m, the designed lowest water diversion level is 830.0m, and the highest water diversion level is 834.0m. The power station is a low-head, large-flow, and river-bed hydropower station. The Yellow River has a large water flow in this section, so the diversion of the project will not change the existing operation mode of the power station and the discharge flow to the downstream, and therefore have a small influence on the aquatic organisms in the downstream rivers and will not damage the ecological integrity and biodiversity of the downstream water ecosystems.

#### 5. Conclusion

The water diversion of the project has a subtle influence on the downstream Tianqiao hydropower station and regional water resources, has little influence on the assimilative capacity of the functional area of the water body, and has a small influence on the hydropower station and its downstream aquatic organisms. In addition, it will play a role in protecting the regional water ecological balance and supplementing and conserving the groundwater in the water receiving area, reduce the amount of groundwater over-extraction in the basin, and improve the water resources and water environment in the water receiving area. The Yellow River Diversion Project in Central China can effectively alleviate the water shortage problem in the water-receiving area, so it is of great significance to regional economic development and the improvement of residents' living standards. The water diversion project basically meets the relevant industrial policies and the requirements for water resources planning, configuration and management, so the water diversion project is reasonable.

#### References

- [1] Guang-Lu H U, Ji-Shi Z, Li-Juan F. *Forecasting and Analysis of the Discharged Water Capacity of Zhengyi Gorge Section in Heihe River Based on SPSS Model*[J]. *Yellow River*, 2013.
- [2] Wang Junquan. *Political Economics Analysis of Water Rights Allocation in the Yellow River Basin* [D]. *Huazhong University of Science and Technology*, 2017.
- [3] You Jinjun, Wang Ting, Jia Ling, Ma Zhenzhen. *Analysis on the Direction and Countermeasures of Rational Regulation of Water Resources Supply and Demand in the Yellow River Basin* [J]. *Land and Resources Information*, 2021(04): 8-17.
- [4] Zhou Jianbo. *Practice of Water Diversion permit System for Yellow River Basin* [J]. *Water Resources Development Research*, 2014, 14(10): 47-52.
- [5] Qi Yonghui, Cheli Muge, Yu Huanghao, Qian Yu, Li Binquan. *Analysis of the Influence of Water Diversion along the Yellow River on Runoff at Major Sections of the Yellow River Main Stream* [J]. *Pearl River*, 2021, 42(05): 42-49.
- [6] Ren Miao. *Prediction and Analysis of the impact of the Yellow River Estuary Power Station on Water Environment* [J]. *Gansu Water Resources and Hydropower Technology*, 2011, 47(05): 12-15.