Analysis of Benefit Regulation of Chongxing Barrage

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Keywords: Barrage; Irrigation; Benefit Regulation

Abstract: water resources are basic natural resources and important strategic resources. The contradiction between water supply and demand is still the main bottleneck of sustainable development. Vigorously developing agricultural water saving and improving irrigation guarantee rate are important measures to promote sustainable utilization of water resources. According to the irrigation task of Chongxing Barrage, this paper designs the barrage project to ensure irrigation by analyzing and calculating the agricultural water demand, river ecological water demand, river evaporation and leakage loss, etc.

1. Project overview

The previous Chongxing Barrage is located at pile numbered 46+590 of the main stream of Laoshu River on the east side of Chongxing Village, Tancheng County, about 2.7km downstream of the G310 Bridge, and about 10.7km away from the upstream Longmen Rubber Dam. The project plays multiple roles, such as water storage, irrigation and ecological environment improvement. The Chongxing Barragewas built in the 1960s. After the safety appraisal, it was rated as category IV, which means that it should be demolished and rebuilt. To ensure that the project can meet the irrigation function after demolition and reconstruction, it is necessary to analyze the benefit regulation of the dam.

2. Water demand analysis

The rebuilt Chongxing Barrage is located on the main stream of Laoshu River, 48km downstream of the barrage of Renmin Shengli Weir in Daguanzhuang Hub. It is responsible for the irrigation of 76,500 mu of farmland in Honghua Town and Gaofengtou Town in Tancheng County. All the domestic and industrial water in this section comes from other water sources, and does not come from the river. The ecological water demand in the river channel should be met first when the Chongxing Barrage is used for water supply.

2.1 Agricultural water demand analysis

2.1.1 Irrigation system and irrigation norm

The irrigated area of Chongxing Barrage is 76,500 mu. Combined with the *Agricultural Development Plan of Tancheng County* and the *2019-2021 Feasibility Study Report on Water-saving Supporting Transformation of the irrigated area of the Qingquan Temple in Linyi Tancheng County*, the main crops in this irrigated area in the planning target year are winter wheat, spring corn, summer corn and summer rice, with planting proportions of 80%, 20%, 15% and 65% respectively.

According to the irrigation situation in this planned irrigated area, combined with on-the-spot investigation, referring to the surrounding irrigation test stations and the data of growth period in Linyi City, Shandong Province in the *Comprehensive Planning of Water Resources in Huaihe River Basin and Shandong Peninsula*, the parameters were determined in a scientific and reasonable manner and the crop irrigation system was formulated. In this summer rice irrigation system design, referring to the high-yield experience of the neighboring Matou irrigated area and the experimental data of Xiaobudong irrigated area in Linyi City, the water-saving irrigation system of "shallow wetting interval and deep storage after rain" was adopted, and the water balance graphic analysis method was adopted for dry crops. In addition, the irrigation system was formulated in combination with the high-yield irrigation experience and experimental data of the masses. The irrigation period is from June to

  DOI: 10.25236/ssehr.2021.055

September for rice, from September to April next year for winter wheat, from June to August for summer corn and from April to June for spring corn.

Based on the irrigation norms of winter wheat, spring corn, summer corn and summer rice, the irrigation norm of farmland in the planning target year was predicted. The base year irrigation water utilization coefficient of this project is 0.63, and the planned irrigation water utilization coefficient in 2030 is 0.7. After calculation, the annual average gross irrigation norm of the irrigation scope of this project is 433m^3/ mu in 2017, and it is planned to reach 390m^3/ mu in 2030. See Table 1 for the prediction results of gross irrigation norm of farmland under various guarantee rates in the irrigation scope of this project.

Table 1 Table of Forecast Results of Gross Irrigation Quota of Irrigated Farmland in 2030 Unit: 10,000 m^3/ mu

Inflow frequency	2017	2030
50%	417	375
75%	491	442
Multi-year average	433	390

2.1.2 Irrigation water consumption

In the planning target year, the irrigated area of the irrigated area will be maintained at 76,500 mu, and there are no other irrigation projects within the water supply range. All the agricultural water demand will be met by this project. See Table 2 for the water demand results of the irrigated area under different water frequency. The annual average water demand of irrigated area is 29.82 million m^3, and the water demand at 50% and 75% inflow frequency is 28.68 million m^3 and 33.8 million m^3 respectively.

Table 2 Table of the Water demand at different guarantee rates in the irrigated area of the Chongxingzha Barrage Unit: 10,000 m^3

Inflow frequency	Water demand
50%	2868
75%	3380
Multi-year average	2982

2.2 Analysis of ecological water demand in river channel

The water demand to maintain certain functions of the river channel includes ecological base flow, sediment transport water demand and aquatic organism water demand [1]. According to the actual situation, different calculation methods can be selected, and reasonable results can be selected by comparison.

To ensure the quality of water resources in important rivers, according to the requirements of water quality in water function areas and minimum ecological water use in rivers, and referring to the results of *National Water Function Zoning of Important Rivers* and *Lakes* and *Comprehensive Planning of Huaihe River Basin* (2012-2030), the minimum ecological flow of main control sections of Shuhe River was formulated. According to the *Water Distribution Plan of Shuhe River*, the minimum ecological discharge at the boundary of Shandong Province and Jiangsu Province is 0.65m^3/s [2].

Chongxing Barrage is located in the upper reaches of the boundary of Shandong Province and Jiangsu Province, and its discharge will directly affect the minimum ecological discharge of provincial boundary section. To ensure the downstream ecological discharge, the minimum ecological discharge of Chongxing Barrage was selected as 0.65m^3/s this time.

2.3 Calculation of water loss

After Chongxing Barrage impoundment, the water surface area is larger than that of natural river channel, and part of the water surface evaporation has changed from land surface evaporation, so it is necessary to consider the increased water evaporation loss after impoundment at Yaoshang Dam. In addition, there are various leakage losses of buildings and foundations in the process of water storage. Under the condition that the benefit storage capacity is determined, these evaporation and leakage losses will reduce the regulated flow of the barrage [3].

2.3.1 Evaporation loss

Evaporation loss of water storage project refers to the evaporation loss increased due to land surface area changing to water surface before the construction of the project:

$$E_Z = E_W - E_L$$

$$E_W = \eta . E_C$$

Wherein: E_Z is the increased evaporation loss, mm; E_L is land surface evaporation, mm; E_W is the natural water surface evaporation, mm; E_C is water surface evaporation, mm; η is the conversion coefficient of evaporating dish, which is subject to E_{601} type evaporating dish, and the conversion coefficient of other evaporating dishes is generally 0.65-0.8; According to the data of water surface and land surface evaporation in Linyi Station, Shandong Province, the increased evaporation loss is water surface evaporation minus land surface evaporation. The calculated annual evaporation loss is distributed to each month according to the monthly distribution number of water surface evaporation to obtain the evaporation loss of each month. Them, the obtained evaporation loss is multiplied by the water surface area corresponding to the average water level of each month to obtain the evaporation loss of each month.

2.3.2 Leakage loss

Leakage includes dam foundation leakage, leakage due to untight gate sealing, reservoir bottom leakage, etc [4]. Commonly used calculation methods include loss rate method and leakage intensity method. The calculation method of loss rate method is:

$$Q_S = \alpha V$$

Wherein: α is the leakage loss coefficient, which is 0-3% per month according to hydrogeological conditions; V is the average water storage capacity of the reservoir during the ΔT period. According to the hydrogeological conditions of the river channel within the scope, the leakage loss coefficient is 2% of the current month's water storage capacity.

3 Benefit regulation calculation

3.1 Dam water level and storage capacity

According to the measured cross-section data between Longmen Rubber Dam and Chongxing Barrage, the water storage capacity and water level storage curve corresponding to different water levels were rechecked as shown in Table 3 and Figure 1.

Table 3 Process table of water level and storage capacity relationship

Water level (m)	Storage capacity (10, 000 m^3)
24	526
25	673
26	875
27	1134
28	1471
29	1891
30	2371
31	2882

32	3414
33	3964

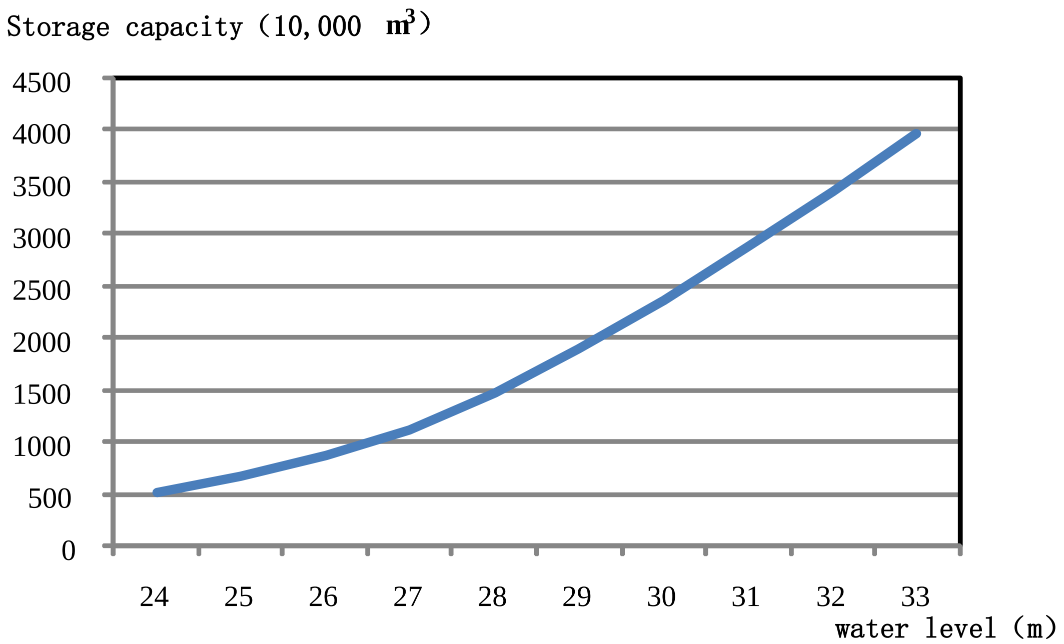

Figure 1 Relationship diagram of storage capacity curve of Chongxing barrage rivers system

3.2 Determination of characteristic water level

3.2.1 Minimum water intake level

The elevation of the bottom of the river at the location of the irrigation intake is about 23.00m, and the elevation of the top surface of the sluice weir is 26.50m. Considering the water intake depth requirement of pumping station for irrigation, it is determined that the lowest water intake level of the Chongxing Barrage of Shuhe River is 30.00m, and the corresponding water storage capacity is 23.71 million m^3.

3.2.2 Normal water level

The normal water level should be determined according to principles including straight river channel, stable riverbed and river regime, good geological and topographical conditions, and coordinating with upstream water storage and inundation, which should generally be lower than the ground elevation on both sides of the river [5]. According to the average elevation of the upstream riverbed, on the premise that backwater will affect farmland planting on both banks as little as possible, the water storage level is raised and the water storage capacity is increased to develop and utilize water resources as much as possible [6].

According to the above principles, the normal water storage level is determined to be 33.00m, the corresponding water storage capacity is 39.64 million m^3, and the benefit storage capacity is 15.93 million m^3.

3.3 The calculation principle of benefit regulation

According to the series of incoming water and water consumption of Chongxing Barrage, based on the principle of water balance [7], considering the ecological water demand, evaporation loss and leakage loss in the river channel, combined with the water level storage capacity curve, the long series calendar from 1958 to 2000 was used to carry out the regulation and calculation of benefits. In the regulation, the water level in the barrage at the end of one month is assumed first, and after trial calculation, the water use guarantee rate is calculated by the formula $P = m/(n+1)$. The adjustment principles are:

First, the adjustment calculation is carried out on a monthly basis.

Second, the starting water level is the lowest water intake level of 30.00m m..

Thirdly, when the water level of the dam is higher than 30.00m and lower than 33.00m, the dam will give priority to the ecological water in the river channel, and then meet the demand of the agricultural irrigation water.

Fourthly, when the water level of the dam is likely to be higher than 33.00m, the water may be properly abandoned to maintain the normal water level.

3.4 Calculation results of benefit regulation

The 47-year data from 1958 to 2020 was used to calculate the average value, and the index values such as water supply and water consumption of Chongqing sluice were predicted. According to the adjustment calculation results, it is planned that the average annual water supply of Chongxing Barrage will be 28.67 million m^3 in 2030, and the guarantee rate of farmland irrigation will reach 75%, which can meet the water demand in the irrigated area. See Table 4 for the calculation results of long-term adjustment.

Table 4 Long-term series diachronic adjustment results of the Chongxing regulation dam plan in 2030 Unit: 10,000 m^3

Hydrologic year	Inflow	Ecological water consumption	Water loss	Agricultural water consumption			Abandoned water quantity
				Planned	Actual	Water shortage	
1958	35064	1675	820	2969	1434	1535	29542
1959	28554	2022	1056	3162	3162	0	22315
1960	102315	2022	1006	2868	2868	0	96420
1961	65820	2022	1035	2582	2582	0	60181
1962	109994	2022	1021	2744	2744	0	104207
1963	102504	2022	1039	2583	2583	0	96861
1964	80793	2022	1037	2722	2722	0	75013
1965	65526	2022	993	3151	3151	0	59360
1966	28006	2022	1017	3451	3451	0	21647
1967	27305	2022	1016	3000	3000	0	21136
1968	15130	2022	994	3451	3451	0	8663
1969	38697	2022	974	2956	2956	0	32745
1970	67953	2022	989	2716	2716	0	62226
1971	109793	2022	1030	2868	2868	0	103873
1972	46709	2022	1035	2722	2722	0	40931
1973	37006	2022	1030	2537	2537	0	31417
1974	101683	2022	1049	2543	2543	0	96070
1975	73185	2022	1045	2611	2611	0	67507
1976	44911	2022	1047	3456	3456	0	38386
1977	12190	2022	992	3364	3364	0	5812
1978	24583	2022	972	3498	3274	224	18315
1979	23698	2022	1004	2952	2952	0	17720

Table 4 Long-term series diachronic adjustment results of the Chongxing regulation dam plan in 2030 Unit: 10,000 m^3

1980	32394	2022	997	3547	3547	0	25891
1981	7837	2022	962	3561	3540	20	1314
1982	26664	2022	976	2543	2543	0	21059
1983	6250	2022	898	3406	3348	58	38
1984	32299	2022	934	2768	2749	19	26539
1985	29949	2022	971	2841	2841	0	24115
1986	18645	2022	955	3487	3487	0	12218
1987	16155	2022	964	2613	2613	0	10520
1988	13185	2022	943	3380	3363	17	7009
1989	3205	1609	785	3427	2252	1175	0
1990	55269	1212	781	2645	1645	1000	50038
1991	47837	2022	987	2643	2643	0	42475
1992	10050	2022	914	3321	3073	248	3870
1993	35774	2022	949	2638	2638	0	30048
1994	48605	2022	995	2633	2633	0	42954
1995	43050	2022	971	2706	2706	0	37351
1996	28259	2022	952	3495	3495	0	21791
1997	27605	2022	952	3312	3312	0	21319
1998	73772	2022	1005	2506	2506	0	68239
1999	22437	2022	922	3172	2508	665	16985
2000	43166	2022	971	2688	2688	0	37486
average	43345	1985	976	2982	2867	115	37479

4. Conclusion

River channel maintenance needs water demand such as ecological base flow, sediment transport and aquatic organisms, and evaporation loss and leakage loss will occur in the process of water use, so accurate calculation of water consumption and inflow is the basis of ensuring irrigation water use. According to the characteristics of agricultural water irrigation, this paper analyzes and demonstrates the irrigation water demand and river water inflow. According to the characteristic water level and water storage capacity of Chongxing barrage, the calculation and analysis of benefit regulation show that the dam water storage can meet the irrigation requirements.

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