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Calculation and Analysis of the Instream Ecological Flow for the Irtysh River

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Abstract

Instream ecological flow is essential determinant of river health. In this paper, the monthly minimum flow calculation method, the (new) monthly frequency calculation method were applied to calculate and evaluate the minimum instream ecological flow and the optimal instream ecological flow for the Irtysh River, and the different criteria of instream ecological flow was calculated by the improved Tennant method. It is expected to provide a scientific basis for the reasonable allocation of water resource in Irtysh River basin by calculating the instream ecological flow.

Keywords: the instream ecological flow; the minimum instream ecological flow; the optimal instream ecological flow; the improved Tennant method; Irthsh River

1. Introduction

Water is one of the basic resources on the planet, which plays a significant role in survival and development of the human society. However, with the economic development, population growth, and environmental pollution and so on, water crisis is becoming more and more serious. Irtysh River is an international river, flowing through China, Kazakhstan and Russia, see Figure 1. It has great significance in economic and social development for each country. In the 1960s, the former Soviet Union built a number of reservoirs on the Irtysh River; these reservoirs changed the flow processes of Irtysh River, and caused the damage to the ecological environment. Figure 2 shows the flow processes of the Omsk station

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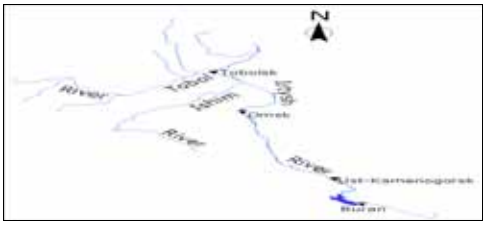
which located in the reservoir downstream, due to the water storage of upstream reservoirs, it cut the peak flow, and also probably made the downstream wetland lack of water supply timely. Therefore, the study on the instream ecological flow of the Irtysh River is necessary, which can make the hydro-power projects reduce the adverse effects on the ecological environment as far as possible, and it also has certain significance for the development of national water allocation.



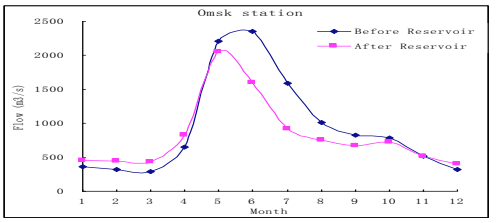


Figure 1..Study area and selected sites (left)
Figure 2. Variation of monthly mean flow at Omsk station before and after upstream reservoirs' construction (right)

2. Data & Methods

2.1. Data

The Irtysh River had been enormously affected by human activities since 1960, so the selected data series were the monthly measured flow records of Buran station (1938-1959), Ust-Kamenogorsk station (1903-1959), Omsk station (1923-1959) and Tobolsk station (1891-1959).

2.2. Methods

There are many ecological flow methods, and the hydrological methodologies include the 7Q10 method, Tennant method and minimum continuous 30 day's mean discharge method, etc [1]. Additionally, there are two methods in China, the monthly minimum flow calculation method [2-3] and the monthly frequency calculation method [4]. These methods based on the recorded hydrological river regime, and assume that a percentage of mean flow will guarantee a certain level of ecosystem protection.

3. Results & Discussion

3.1. The minimum instream ecological flow of Irtysh River

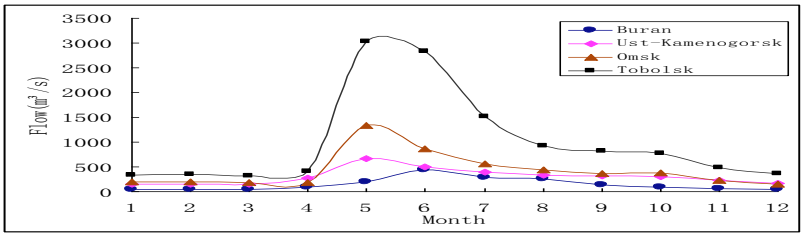


Figure 3. The minimum instream ecological flow of Irtysh River

The minimum instream ecological flow was calculated by the monthly minimum flow calculation method. Figure 3 shows the result, the minimum instream ecological flow is increasing from upstream to downstream; and the flows in May-July are larger than other months.

3.2. The optimal ecological flow of Irtysh River

The optimal instream ecological flow was calculated by the monthly frequency calculation and the new monthly frequency calculation method [4], see Table 1. From the results, the optimal ecological flow values calculated by the Method 2 are larger than the Method 1 except the flows in the flood season.

Table 1. The optimal instream ecological flow of Irtysh River (m3/s)

Month	Buran		Ust-Kamenogorsk		Omsk		Tobolsk	
	Method 1	Method 2	Method 1	Method 2	Method 1	Method 2	Method 1	Method 2
1	46.7	58.3	184.2	249.5	254.6	347.7	432.5	590.9
2	46.0	56.0	169.9	235.7	222.7	300.6	406.0	550.2
3	45.3	60.6	182.5	254.4	216.8	274.3	378.6	512.4
4	153.2	189.3	558.8	667.0	480.6	610.5	554.1	907.7
5	651.5	651.5	1366.8	1366.8	2146.0	2146.0	4826.3	4826.3
6	1065.1	1065.1	1234.3	1234.3	2293.4	2293.4	5458.0	5458.0
7	647.4	647.4	821.0	821.0	1557.1	1557.1	4130.0	4130.0
8	334.0	382.0	590.5	690.7	789.6	946.2	2009.4	2517.3
9	194.7	235.2	518.3	606.1	644.1	767.9	1382.9	1698.0
10	121.6	141.5	444.7	527.8	616.5	724.7	1223.1	1474.4
11	66.4	93.8	259.7	361.8	314.8	486.8	638.6	950.4
12	46.4	60.7	204.6	278.4	210.2	296	502.8	722.4

Notes: Method 1 refers to the monthly frequency calculation method; Method 2 refers to the new monthly frequency calculation method.

3.3. Calculation by the improved Tennant method

The Tennant method was proposed by Tennant, it has always been used to calculate the recommended flows or as a basis to test other methods, but the Tennant method was not sufficient to accord with the river hydrological characteristics. In this paper, the typical year flow processes replace the average annual flows, to some extent; it makes up the deficiencies of the Tennant method. Because the percentage coefficients are based on the ecological test in the river, the typical year flow processes can better reflect the flood season and dry season than the average annual flow [5-6].

3.3.1. The improved Tennant method

In view of the basic features ecological system of Irtysh River, in this paper, the ecological flow was divided into three periods (May-Jul, Aug-Oct and Nov-Apr). By introducing the seasonal coefficient k, to make the Tennant Method can reflect the seasonal flow changes. Assuming the typical year's flow process was Q_t, and the average annual flow was Q_0, so the seasonal coefficient was:

$$k = Q_t / Q_0$$

Then k multiplied by the recommended base flow as the new percentage coefficients, and the Tennant method could be suitable for seasonal variation of river flows.

3.3.2. Comparison of the Results

According to the improved Tennant method, the different criteria ecological flows of the four stations of Irtysh River were calculated (Table 2). From the table, it can be seen that the optimal ecological flow calculated by the new monthly frequency method is more favourable than the monthly frequency method. Taking Omsk as an example, the optimal ecological flow calculated by the monthly frequency method which the month in April, May, June and November were in the "Optimal Range", the rest of months were in the "Outstanding", while calculated by the new monthly frequency method which the month in July and October were in the "Outstanding", the rest of months were all in the "Optimal Range".

Table 2. Criteria of ecological water requirements at representative stations of Irtysh River

Station	Period	Average flow	Criteria of ecological flow(m^3/s)							
			Flushing	Optimal Range	Outstanding	Excellent	Good	Fair	Poor	Severe Degradation
Buran	5-7	913.7	2055.2	616.6-1027.6	616.6	513.8	411.0	308.3	102.8	0-102.8
	8-10	300.3	640.6	192.2-320.3	192.2	160.2	128.1	96.1	32.0	0-32.0
	11-4	87.7	165.1	56.5-82.5	33.0	24.8	16.5	8.3	8.3	0-8.3
Ust-Kamenogorsk	5-7	1220.7	2551.0	765.3-1275.5	765.3	637.7	510.2	382.6	127.5	0-127.5
	8-10	632.0	1267.8	380.4-633.9	380.4	317.0	253.6	190.2	63.4	0-63.4
	11-4	315.0	565.3	169.6-282.7	113.1	84.8	56.5	28.3	28.3	0-28.3
Omsk	5-7	1866.7	3391.1	1017.3-1695.6	1017.3	847.8	678.2	508.7	169.6	0-169.6
	8-10	933.0	1995.1	598.5-997.5	598.5	498.8	399.0	299.3	99.8	0-99.8
	11-4	379.3	699.5	209.8 -349.7	139.9	104.9	69.9	35.0	35.0	0-35.0
Tobolsk	5-7	5670.0	8638.3	2591.5-4319.2	2591.5	2159.6	1727.7	1295.8	431.9	0-431.9
	8-10	2170.0	4565.4	1369.6-2282.1	1369.6	1141.4	913.1	684.8	228.3	0-228.3
	11-4	686.5	1226.1	367.8-613.0	245.2	183.9	122.6	61.3	61.3	0-61.3

4. Conclusion

In this paper, the instream ecological flow in the Irtysh River basin was calculated and evaluated, and the results as followed:

(1) The minimum instream ecological flow for the Irtysh River was a continuous process of change in a year, and it was just a limitation of the instream ecological flow, which should not be maintained for a long time, otherwise it is very negative for the healthy life of river.

(2) The optimal instream ecological flow values, calculated by Method 2 were larger than Method 1. That is to say, the results calculated by the Method 2 can raise the guarantee for the health of Irtysh River.

(3) The improved Tennant method can reflect the processes of hydrological changes by introducing the seasonal coefficient. So we cannot rigidly stick to Tennant method's original determined phases, which can be classified based on the specific location, climatic conditions, ecological protection and so on.

Acknowledgements

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