Analysis of Influencing Factors and Application Prospect of Defunctionalization in Sanggan River

Jiajia Li

School of Environment, Hohai University, Nanjing 210098, China

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Abstract: With the implementation of water ecological civilization construction, river and lake ecological recovery has gradually become an important proposition of river and lake protection in the new era and the new journey. On the basis that the change trend of runoff, water quality, biology, geomorphology, social economy and other factors of Sanggan River. The concept of river channel defunctionalization is proposed for the first time, the thesis establishes the evaluating standard system by analytic hierarchy process (AHP), comprehensively evaluates the river defunctionalization, and puts forward the river function restoration measures according to the degradation trend of river eco-environment: Maintain the river ecological base flow; Change the irrigation mode of farmland around the river, reasonable fertilization; Improve sewage treatment capacity, rational use of reclaimed water; Conserve water sources and maintain soil and water. The joint implementation of the above measures will provide technical support for the ecological recovery of the Sanggan River. The severity of the disablement of Sanggan River fully indicates that the development and utilization of water resources should pay attention to the holistic concept, prevent overexploitation, and pay attention to the protection of water ecological environment security. The development and utilization of water resources must be considered comprehensively, planned comprehensively and subject to the construction of water ecological civilization under the premise of ensuring the safety of ecological environment and sound river function.

1. Introduction

With the implementation of water ecological civilization construction, the ecological recovery of rivers and lakes has gradually become an important mission to carry the rivers and lakes protection work forward in the new era and new journey [1-3]. Taking Sanggan River as an example, this thesis analyzes the process that the basic functions and purposes of rivers are gradually weakened or even lost under natural or human action. The concept of river defunctionalization is proposed for the first time. At present, most of the research results are only single factor analysis of the river function degradation factors, and no comprehensive evaluation system of river function defunctionalization has been established. In response to the factors affecting the defunctionalization of the Sanggan River [4-5], this thesis analyzes the changing trend of river ecological environment, establishes the evaluation standard system by AHP, comprehensively evaluates the river ecological environment, and formulates irrigation methods to maintain the ecological base flow of the river and change farmland around the river, provides measures such as reasonable fertilization, improving sewage treatment capacity, utilizing recycled water reasonably, conserving water sources, and maintaining soil and water to delay the trend of defunctionalization, offering technical reference for river environmental protection and water ecological restoration in Hebei Province and even the whole country.

2. Analysis of Influencing Factors of Channel Defunctionalization

2.1. Runoff

Select a series of data from the Shixiali Hydrological Station in Sanggan River, and Pearson type III curve is used for frequency analysis and calculation in three periods of Cetian Reservoir: before construction (1950-1959), after construction (1960-2014) and in the near future (2000-2014), as shown in Table 1.

Table 1 Summary of analysis results of Sanggan river under different periods of high flow year, Normal Flow Year and low flow Year

Time	Designed annual runoff		Representative Year	Maximum flow (m^3/s)	Minimum flow (m^3/s)	Annual sediment discharge (10,000 t)	Remarks
	Run-off (100 million m^3)	Proportion (%)					
Before construction (1950-1959)	16.9	71.82%	1954	1400	0.200	10700	High flow year
After construction (1960-2014)	6.63	28.18%	1979	182	2.72	404	
Recent (2000-2014)	0.974	4.14%	2003	39.7	0.026	6.96	
Before construction (1950-1959)	10.9	84.56%	1957	524	3.20	2530	Normal flow year
After construction (1960-2014)	1.99	15.44%	1984	48.6	1.09	27.9	
In the near future (2000-2014)	0.573	4.45%	2010	22.7	0	3.01	
Before construction (1950-1959)	7.29	93.85%	1952	1190	0.400	5080	Low flow year
After construction (1960-2014)	0.478	6.15%	2012	21.6	0	0.800	
In the near future (2000-2014)	0.320	4.12%	2009	5.60	0	0.640	

According to the analysis, Whether it's a high flow year, normal flow year or low flow year, the proportion of annual runoff is obviously decreased from “before construction”, “after construction” to “the near future”, and the minimum monthly average discharge for many years is 11.3 m^3/s, 3.20 m^3/s and 0.422 m^3/s respectively. The construction of Cetian Reservoir intercepts upstream water, causing a sharp decrease in downstream annual runoff, narrowing of the river surface, elevation of the riverbed, and weakened flood carrying capacity, which is highly prone to triggering flood disasters. After 1960s and 1970s, the soil and water conservation engineering in the basin had blocked the surface runoff, and many river sections are basically in a state of cutoff. The phenomenon of random sand mining in the river became more and more serious, and the exposed riverbed and bank slope were changed beyond recognition.

2.2. Water Quality

2.2.1. Surface Water Quality

According to the water quality data of Zhuolu Baozhuang Station and Yangyuan Shixiali Station (see Table 2), during 2007-2015, the conventional ion concentration of the reaction chemistry type in the water shows an upward trend. Take sulfate as an example, the sulfate concentration of the two stations has an obvious rising trend, as shown in Figure 1.

Table 2 Monitoring Data Sheet of Main Chemical Ions in Surface Water (Unit: mg/L)

Year	Station Name	PH (dimensionless)	Salinity	Carbonate	Bicarbonate	Total hardness	Calcium	Magnesium	Chloride	Sulphate
2007	Baozhuang	8.2	649.8			133.0			65.4	76.9
2008	Baozhuang	8.4	587.0			156.0			63.8	71.6
2009	Baozhuang	8.3	471.3			202.0			64.2	96.1
2010	Baozhuang	8.4	546.2			243.0			47.1	168.0
2011	Baozhuang	8.3	549.0			153.0			72.6	58.6
2012	Baozhuang	8.5	609.7			155.0			73.4	75.3
2013	Baozhuang	8.4	681.6			213.0			65.4	128.3
2014	Baozhuang	8.4	725.0			329.5			50.5	95.5
2015	Baozhuang	8.2	630.3	3.0	264.5	239.7	23.5	42.5	79.0	87.7
2007	Shixiali	7.9	634.7	0.0	298.3	182.7	48.8	49.5	54.5	86.8
2008	Shixiali	8.2	506.0	3.9	313.5	162.5	61.7	33.0	56.0	52.8
2009	Shixiali	8.3	491.7	5.3	284.7	139.7	51.5	29.2	56.2	50.3
2010	Shixiali	8.3	546.0	9.4	264.0	179.5	42.5	52.1	58.3	58.9
2011	Shixiali	8.2	554.0	4.5	285.0	148.0	34.7	43.1	69.5	53.8
2012	Shixiali	8.3	587.0	4.1	295.3	144.3	34.5	41.6	77.0	75.0
2013	Shixiali	8.3	758.3	24.2	293.0	271.3	38.2	58.8	107.0	135.2
2014	Shixiali	8.4	724.7	7.4	405.0	294.3	33.0	51.3	56.0	99.7
2015	Shixiali	8.1	654.3	2.5	329.7	253.3	22.3	48.0	87.0	116.3

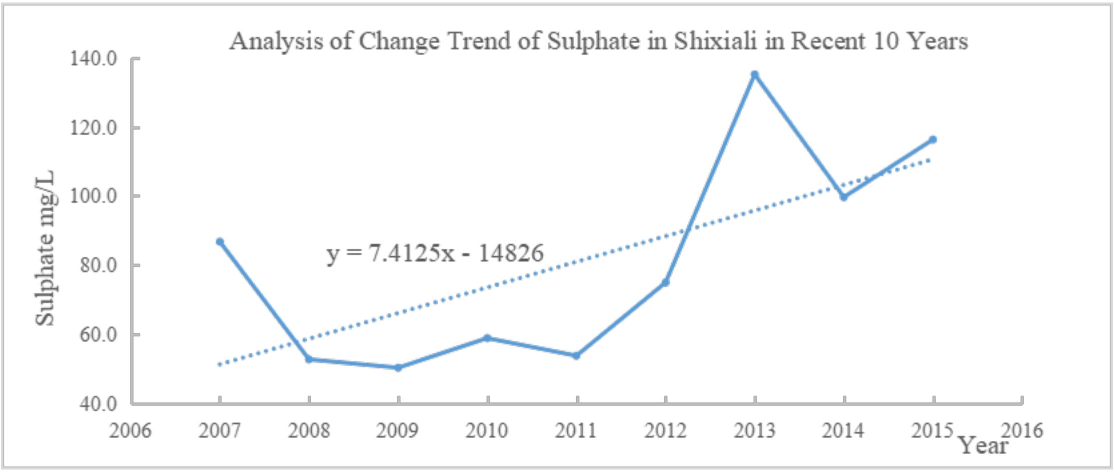

Figure 1 Analysis of change trend of sulphate in Shixiali in recent 10 years

2.2.2. Groundwater Quality

According to the water quality data of Futujiang Station of Yangquan County and Lijiabao Station of Zhuolu County (Table 3), during 2007-2015, the general trend of pH value and various chemical types of ions is increasing. Take chloride as an example, the chloride ion concentration of the two stations increases obviously, as shown in Figure 2.

Table 3 Statistical Table of Main Ion Data of Groundwater (Unit: mg/L)

Year	Station Name	PH (dimensionless)	Total hardness	Chloride	Sulphate	Salinity
2005	Futujiang	7.7	460	50.9	50.8	672
2006	Futujiang	8.0	419	42.3	29.2	565
2007	Futujiang	7.7	398	38.3	24.6	689
2008	Futujiang	8.1	471	68.8	37.8	791
2009	Futujiang	8.1	313	48.6	140	532
2010	Futujiang	7.7	574	70.0	157	867
2011	Futujiang	8.2	525	64.0	36.0	786
2012	Futujiang	8.2	594	102	38.7	913
2013	Futujiang	8.4	573	108	78.0	1074
2014	Futujiang	8.4	637	134	76.0	1120
2005	Li Jiabao	8.0	166	-	14.8	340
2006	Li Jiabao	8.1	154	-	-	425
2007	Li Jiabao	8.0	141	-	-	508
2008	Li Jiabao	8.2	274	26.2	23.6	433
2009	Li Jiabao	8.2	327	24.8	69.9	431
2010	Li Jiabao	7.7	240	25.5	16.9	380
2011	Li Jiabao	8.1	317	35.3	28.3	490
2012	Li Jiabao	8.4	377	33.2	68.8	469
2013	Li Jiabao	8.2	279	31.8	51.5	534
2014	Li Jiabao	8.4	292	32.7	71.0	543

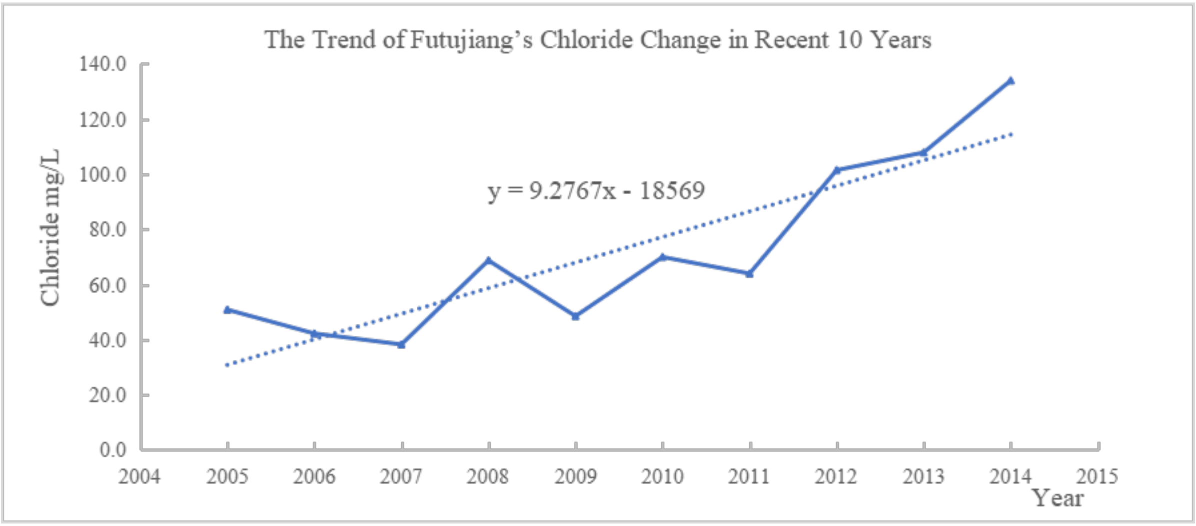

Figure 2 The trend of Futujiang's chloride change in recent 10 years

2.2.3. Salinization

Salinization is relatively severe in the basin, with some areas experiencing severe salinization. The salinization gradually extending from the river to both banks in a radial shape, and the salinization area generally links up into a single stretch. According to the monitoring data of soil salinization near Sanggan River [6] Chuaigutuan, it can be seen that the soil salinization at the depth of 10cm is very serious. Generally, the soil salinization degree on the surface is more serious than that inside the soil, as shown in Table 4.

Table 4 Monitoring data of soil salinization in Sanggan River (Unit: mg/L)

Sample No.	Sample Information	PH	Total hardness	Sulphate	Chloride	Remarks
1	1#	9.3	140	142	1810	Parallel sampling for 1# and 2#
2	1# D=10cm	8.2	300	186	720	
3	2#	8.6	500	476	2460	
4	2# D=10cm	7.8	300	141	521	
5	3#	8.9	721	396	593	Parallel sampling for 3# and 4#
6	3# D=10cm	10.1	250	520	742	
7	4#	9.2	681	422	444	
8	4# D=10cm	12.1	440	572	768	
9	5#	10.9	240	570	1680	Parallel sampling for 5# and 6#
10	5# D=10cm	8.2	1200	396	692	
11	6#	10.3	300	560	1930	
12	6# D=10cm	8.7	1240	169	648	

2.3. Biological

There are approximately 8 species of aquatic organisms in Sanggan River with an average area of 100 m^2, including fish (grass carp, carp, catfish), shrimp, turtle, clam, frog and other algae mayfly. Generalized the selected water area of 100 m^2 into 10 square water areas with the same area, the diversity index is about 3.5. The diversity index is calculated by Gleason index [7] formula. The ratio of the area of the water area to 100 m^2 is selected as the generalized area of the water area. The average diversity index of aquatic organisms is about 1.20.

2.4. Geomorphology

The north section length of Sanggan River is 204.60 km, and the central line of the basin is 135 km. After completion of Cetian Reservoir of Sanggan River, the downstream flow decreased sharply or even disappeared, and reclamation of farmland was very serious. The original river width of 200 m-1500 m was "blocked" into 30 m-50 m, and the part was less than 10 m. Some river sections have the phenomenon of indiscriminate mining and excavation. The length of the disorderly sand mining channel in study area is about 18 km, and the random sand mining rate is 8.8%.

2.5. Social Economy

According to 2014 Water Resources Bulletin of Zhangjiakou, the development and utilization amount of surface water in the basin is 193.3 million m^3, and the annual runoff after construction is 119 million m^3 in normal flow year. The development and utilization rate of surface water resources is 70%, and the water consumption per unit GDP is 83.00 m3/10,000 yuan.

3. Comprehensive Analysis of Degree of Defunctionalization

In accordance with the five attributes of hydrology, water quality, geomorphology, biology and social economy in the basin, the fuzzy mathematics evaluation method [8] is adopted to build the standard evaluation system, evaluating the degree of defunctionalization at 5 levels: none, inconspicuous, obvious, severe, and very severe See Table 5.

AHP [9,10] is adopted to determine the weight of attribute layer, emphasizing the dependency of biology and social economy on hydrological and water quality attribute indexes. See Table 6 for the established judgment matrix.

The diagonal matrix composed of eigenvector and eigenvalue can be obtained by MATLAB, and maximum eigenvalue of comparison matrix: λ_{max}=5.2308, the eigenvector is (0.2206, 0.1393, 0.5122, 0.8143, 0.0803). After the normalization of the eigenvector, the weights of the 5 primary indexes are WB=(0.1249, 0.0788, 0.2899, 0.4609, 0.0455).

Check the consistency of the comparison matrix. The consistency ratio can be obtained by the formula CR=CI/RI. The random consistency indexcan be found from Table 7, and RI of the 5-order matrix is 1.12.

Table 5 Defunctionalization Indexes and Evaluation Criteria of Sanggan River

Attribute Layer	Index layer	Department	Index value	Grading Criteria				
				No	Inconspicuous	Obvious	Serious	Very serious
Hydrology	Monthly average flow change rate	—	0.45	0-0.2	0.2-0.4	0.4-0.6	0.6-0.8	0.8-1
	Minimum environmental water demand satisfaction rate	%	3.7	95-100	80-95	60-80	40-60	0-40
Water quality	Water quality category	—	4	0-1	1-2	2-3	3-4	4-5
	Dirt-holding property	%	23.7	0-20	20-30	30-40	40-50	50-100
Geomorphology	Meandering degree	—	1.52	3-4	2-3	1.4-2	1.2-1.4	1-1.2
	Disorderly sand mining rate	%	8.8	0-1	1-2	2-3	3-10	10-100
Biology	Species diversity	—	1.20	4.5-3.5	2.5-3.5	1.5-2.5	1-1.5	0-1
	Survival status of rare aquatic organisms	%	0	95-100	85-95	75-85	65-75	0-65
Social economy	Development and utilization rate of surface water resources	%	70	0-20	20-40	40-50	50-60	60-100
	Water consumption per unit of GDP	—	83	0-5	5-20	20-30	30-40	40-90

Table 6 Judgment matrix of attribute layer

Interdependence	Hydrology	Water quality	Geomorphology	Biology	Social economy
Hydrology	1	2	1/3	1/5	4
Water quality	1/2	1	1/5	1/6	3
Geomorphology	3	5	1	1/2	5
Biology	5	6	2	1	6
Social economy	1/4	1/3	1/5	1/6	1

Table 7 Random consistency index RI value table

Order	*RI*	Order	*RI*	Order	*RI*	Order	*RI*
1	0	6	1.26	11	1.52	16	1.5943
2	0	7	1.36	12	1.54	17	1.6064
3	0.52	8	1.41	13	1.56	18	1.6133
4	0.89	9	1.46	14	1.58	19	1.6207
5	1.12	10	1.49	15	1.59	20	1.6292

The Consistency Index (CI) can be calculated according to the formula

$$CI = \frac{-1}{n-1}\sum_{i=2}^{n}\lambda_i = \frac{\lambda_1 - n}{n-1} = \frac{\lambda_{max} - n}{n-1} \quad (1)$$

Get. So there is

$$CR = \frac{CI}{RI} = \frac{\frac{5.2308-5}{5-1}}{1.12} = 0.05152 \quad (2)$$

Consistency ratio CR<0.1, which meets consistency requirements, indicating that the constructed attribute level comparison matrix has passed the consistency test.

The membership function adopts Cauchy distribution function [11], and distinguishes the models with index values at different levels of defunctionalization, in order to more reasonably evaluate the degree of defunctionalization at different levels.

Determine the membership of the index that belong to levels I, II, III, IV, and V using the Cauchy membership function, that is,

$$\mu(x) = \frac{1}{1+\alpha(x-a)^{\beta}} \quad (3)$$

μ(x)——membership function

x——index value

α、β——function parameter, β=2

When the index value is at the midpoint of levels II, III and IV ,μ(x)＝1; when the index value is at the critical point of levels II, III and IV, μ (x)=0.5; when the index value is at the left end point of level I and the right end point of level V, μ (x)=1; for levels II, III and IV

$$a = \frac{x_u + x_l}{2} \quad (4)$$

For Level I

$$a = x_l \quad (5)$$

For Level V

$$a = x_u \quad (6)$$

For levels I, II, III, IV and V, α takes the same value

$$\alpha = \frac{4}{(x_u - x_l)^2} \quad (7)$$

Where

x_u -upper boundary value of corresponding parameter of corresponding level
x_l——lower boundary value of corresponding parameter of corresponding level.
Combined Table 7 with the Cauchy distribution function, the membership matrix R is

0.0471	0.3077	0.8000	0.1379	0.0320
0.0007	0.0079	0.0222	0.0446	0.9669
0.0154	0.0385	0.1000	0.5000	0.2000
0.1511	0.9367	0.1637	0.0522	0.0969
0.0391	0.2065	0.7353	0.1712	0.0357
0.0032	0.0047	0.0063	0.6984	0.1958
0.0224	0.0716	0.2809	0.9615	0.8621
0.0006	0.0031	0.0039	0.0051	1.000
0.0200	0.0588	0.0385	0.1000	0.3077
0.0009	0.0112	0.0074	0.0107	0.9273

Calculate the index weight according to the following formula

$$W_i = \frac{x_i}{\frac{1}{n}\sum_{j=1}^{n} a_{ij}} \quad (8)$$

In the formula:
W_i——Index Weight
x_i——Measured value of index
a_{ij}——Representative value of classification standard
Normalization processing is carried out after calculation, and the weight matrix Wc of the index layer to the attribute layer is obtained as

0.5595	0.0968	0.5595	0.4899	0.0968	0.6175	0.0268	0.0000	0.5369	0.8512
0.1865	0.1078	0.1865	0.1960	0.1355	0.2058	0.0893	0.0000	0.1790	0.0774
0.1119	0.1348	0.1119	0.1400	0.1992	0.1235	0.1339	0.0000	0.1193	0.0340
0.0799	0.1887	0.0799	0.1089	0.2606	0.0475	0.2143	0.0000	0.0976	0.0243
0.0622	0.4718	0.0622	0.0653	0.3079	0.0056	0.5357	1.0000	0.0671	0.0131

Calculate the evaluation matrix B according to $B = Wc \circ R$. Among them, "∘" is a fuzzy synthesis operator, which uses $M(\cdot, +)$ type synthesis operator to complete the fuzzy mathematical evaluation of the indicator layer on the attribute layer, and obtains the evaluation matrix B as

0.1269	0.7193	0.6955	0.9232	1.3729
0.0530	0.2957	0.3358	0.4055	0.4155
0.0418	0.2296	0.3163	0.3461	0.3848
0.0387	0.2066	0.3500	0.3589	0.4675
0.0401	0.1956	0.4606	0.6478	1.9837

Complete the evaluation of the attribute layer on the target layer according to $S = W_B \circ B$, the evaluation matrix S is normalized to:

0.0290	0.1588	0.2167	0.2476	0.3478

According to the principle of maximum membership, it can be inferred that Sanggan River is in the degree of "very serious" of defunctionalization.

4. Countermeasures

4.1 Maintain Ecological Base Flow of River

The minimum annual runoff of Sanggan River is only about 3.7% of the river ecological base flow as a result of precipitation in recent years. Execute the trans-provincial river allocation scheme issued by the state to the letter to ensure ecological flow and provide guarantee for the ecological recovery of Sanggan River.

4.2. Change the Irrigation Mode of Cultivated Land Around the River and Apply Fertilizer Reasonably

Change the flood irrigation and canal irrigation methods of farmland along the river, replace them with sprinkler irrigation and drip irrigation, reduce the mining output of groundwater, apply fertilizer reasonably, and avoid causing soil hardening and secondary salinization and man-made destruction of the ecological environment.

4.3. Improve Sewage Treatment Capacity and Reasonably Utilize Recycled Water

Enlarge the construction and upgrade of municipal wastewater treatment plant, improve the treatment and recycling of wastewater, increase the amount of available water, enhance the utilization rate of recycled water and reduce pollution.

4.4. Conservation of Water Sources, Soil and Water

Planting drought-resistant and alkali-tolerant trees in the surroundings along the river to maintain the scope of the river and prevent excessive reclamation of the channels. Biological and chemical methods were used for intertidal zone. Strengthen the management of sand mining in channels, put an end to illegal sand mining activities, delimit and strengthen the management of prohibited mining areas and reserved areas, in order to ensure the flood control safety and river regime stability. Dredging shall be conducted for silted and diverted river sections to keep a smooth and straight river.

5. Conclusion

The degree of defunctionalization of Sanggan River fully shows that the development and utilization of water resources should attach importance to the whole concept, prevent over-exploitation and pay attention to the safety of water ecological environment. The development and utilization of water resources must be comprehensively considered and planned in an all-round way, subject to the construction of water ecological civilization while ensuring ecological environment safety and sound river function.

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