XVIII World Water Congress
International Water Resources Association (IWRA)

Joint disposals of multi-source water resources for rehabilitating healthy water cycle in Lake Dianchi basin

Gang Chen

Yunnan Survey and Design Institute of Water Conservancy and Hydropower

XVIII WORLD WATER CONGRESS Water for All Harmony between Humans and Nature

第18届 世界水资源大会 水与万物: 人与自然和谐共生

XVIII World Water Congress
International Water Resources Association (IWRA)

Content

- Background
- Methods
- Results and discussion
- Conclusions

1 Background

Under the combined influence of climate change and intensified human activities, lake basins are faced with a series of water issues, such as water shortage, environmental deterioration, and ecological degradation. The water cycle carries the formation and transformation of various forms of water on the Earth, interacting with water environment, water ecology and other processes.

With the rapid population growth and urban expansion in the basin since the 1980s, the water quality of Dianchi Lake and its main into-lake rivers was Inferior Class V, facing severe ecological and environmental issues and becoming one of 'the three lakes', which should be protected in priority in China.

The 'six major projects' have been roughly completed, and the water quality of Lake Dianchi have been significantly improved, but there is still a big gap between the management effectiveness and the public expectation due to lack of joint operation. The objective of this study is to extend the concept of urban healthy water cycle at basin scale to integrate the 'six major projects' into an organic whole with the water cycle as the link, so as to implement the joint disposals of multi-source water resources for rehabilitating the healthy water cycle in the Dianchi Lake basin.

Fig.1 The 'six major projects' in Lake Dianchi

2 Methods

2.1 Study area

The study area is the Lake Dianchi basin with a total area of 2920 km^2, located in central Yunnan, southwest China. The catchment is a semi-closed lake basin with only one natural outlet called the Haikou River, which drains into the Yangtze River. Almost one-tenth of the catchment is covered by Lake Dianchi, China's sixth-largest freshwater lake, which has a surface area of 311 km^2.

The Lyfeng Sluice Gate was built at the outlet river to mitigate the increasing conflict between flood control and water supply. In 2012, the local government formulated an revised operational plan for lake regulation, for which the water level of Lake Dianchi was regulated within the range of 1885.5 m (lower limit) and 1887.5 m (upper limit).

In 2013, the Niulanjiang-Dianchi Water Transfer (NLDCWT) project was built to transfer an annual mean 572 million m^3 of freshwater from outside the basin into Lake Dianchi to dilute the polluted water.

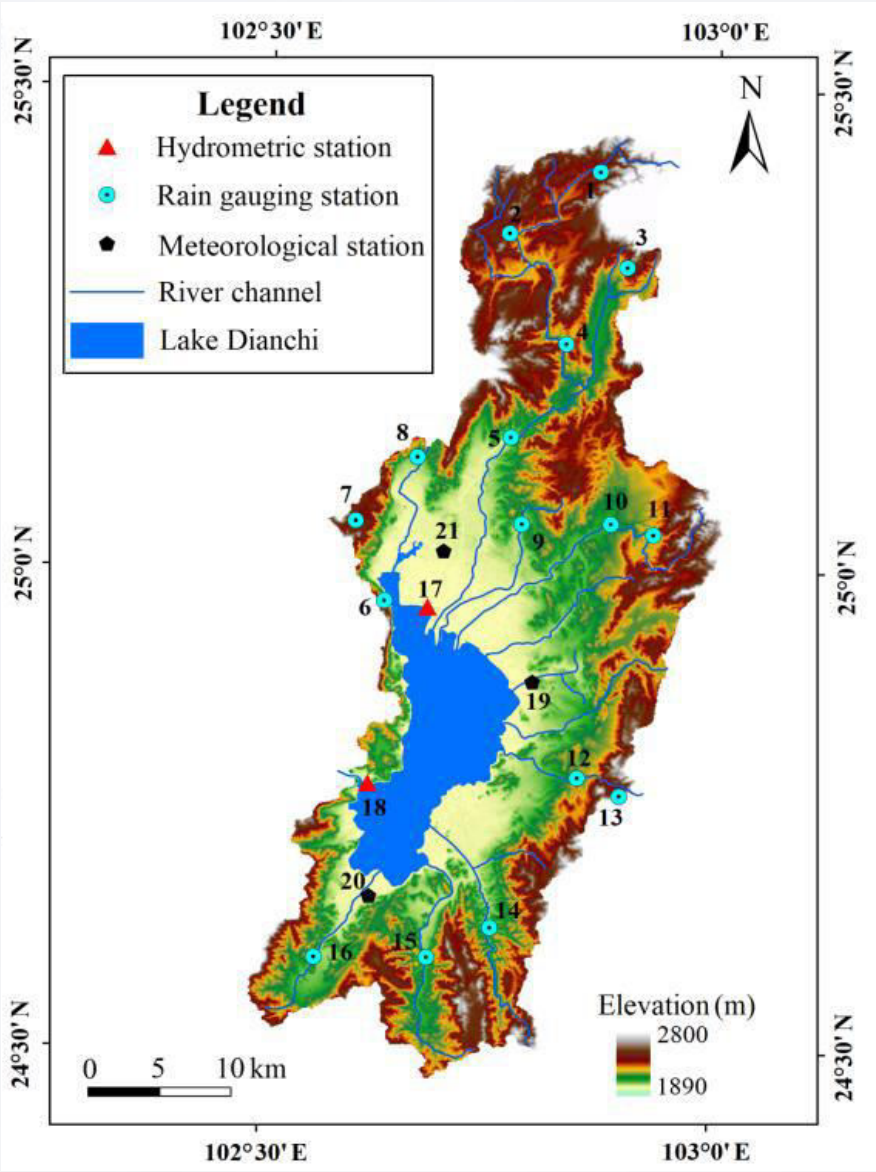


Fig.2 The Lake Dianchi basin

2.2 Connotation and framework of healthy water cycle

Under the background of tight resource and environmental constraints, the overall goal of constructing a healthy water cycle in the basin is (1) to realize the joint regulation of multi-source water in the basin; (2) to improve the regional ecological environment; and (3) to promote the coordinated and sustainable development of the three systems linked by the water cycle through reasonable allocation of limited water resources in the basin.

Principle: Reduction, Reuse, Recycle (3R) at basin scale

Criterion: Clean water discharging into the lake
Reclaimed water reuse
Water saving and ecological priority
Systematic allocation

Dualization: Natural water cycle
Social water cycle

Pathway: Combined the 'six major projects' as an organic whole.

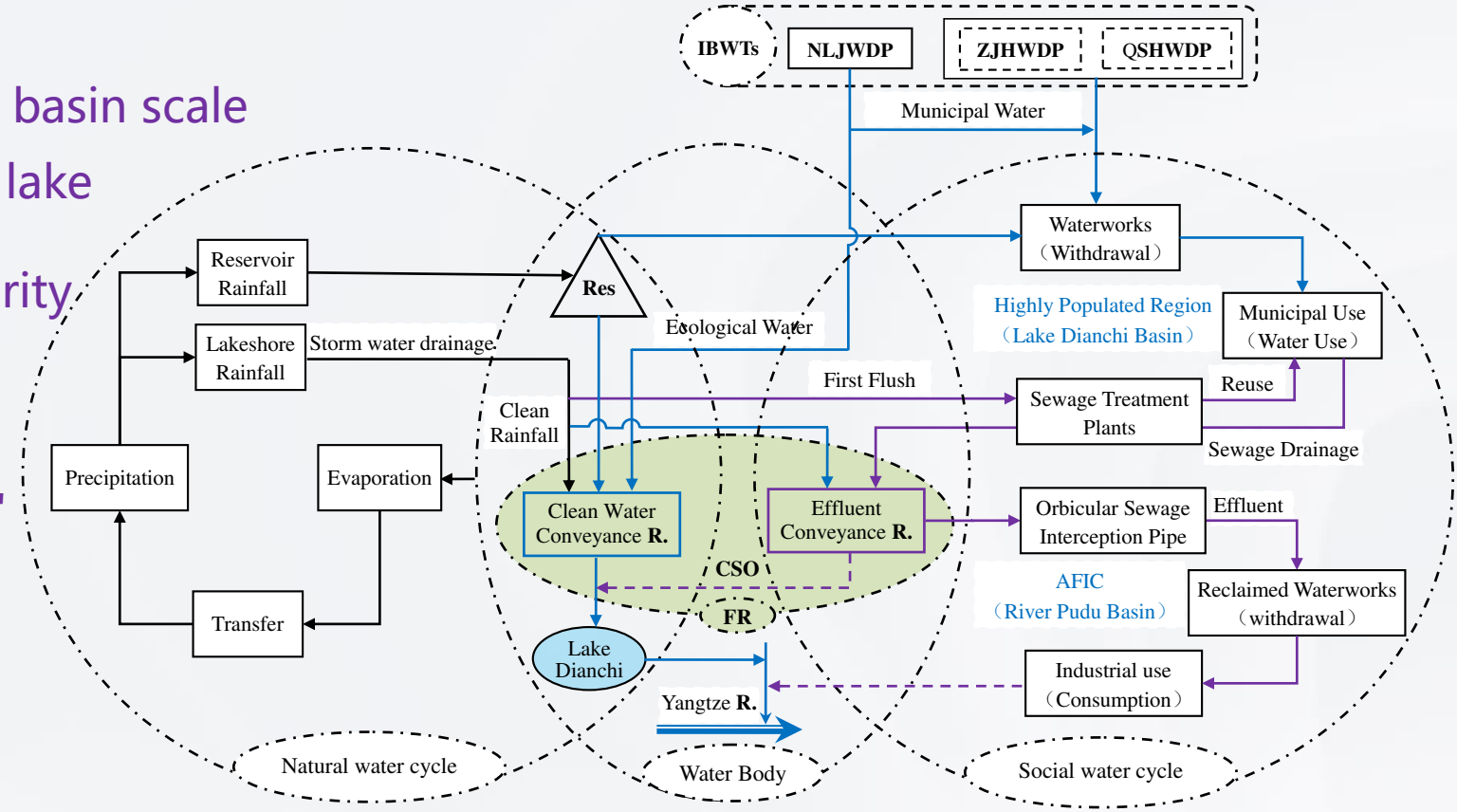


Fig.3 Framework for joint disposals of multi-source water

2.3 Water resources optimal allocation model

Software: MIKE BASIN (DHI)

Node number: 138

Time series: 1956-2015

Time step: monthly

Zoning number: 12

Region	Subregion	Res.	Res.I	Res.II	WT	WDP	User	WL	River	Total
Dianchi Lake Basin	KMzhucheng	2	3	1	3	1	6	3	2	21
	XShaikou	0	0	2	1	1	4	0	1	9
	PLsonghua	0	2	1	0	2	3	0	1	9
	GDxiaoshao	1	0	2	2	1	5	2	1	14
	CGlongcheng	2	4	2	2	1	4	4	3	22
	JNkunyang	1	5	2	1	0	5	1	1	16
	Total	6	14	10	9	6	27	10	9	91
ANIC	WHxizhu	0	2	1	1	1	4	0	1	10
	ANlianran	5	2	2	1	5	8	0	4	27
	FMyongding	0	1	2	1	1	4	0	1	10
	Total	5	5	5	3	7	16	0	6	47
Total		11	19	15	12	13	43	10	15	138

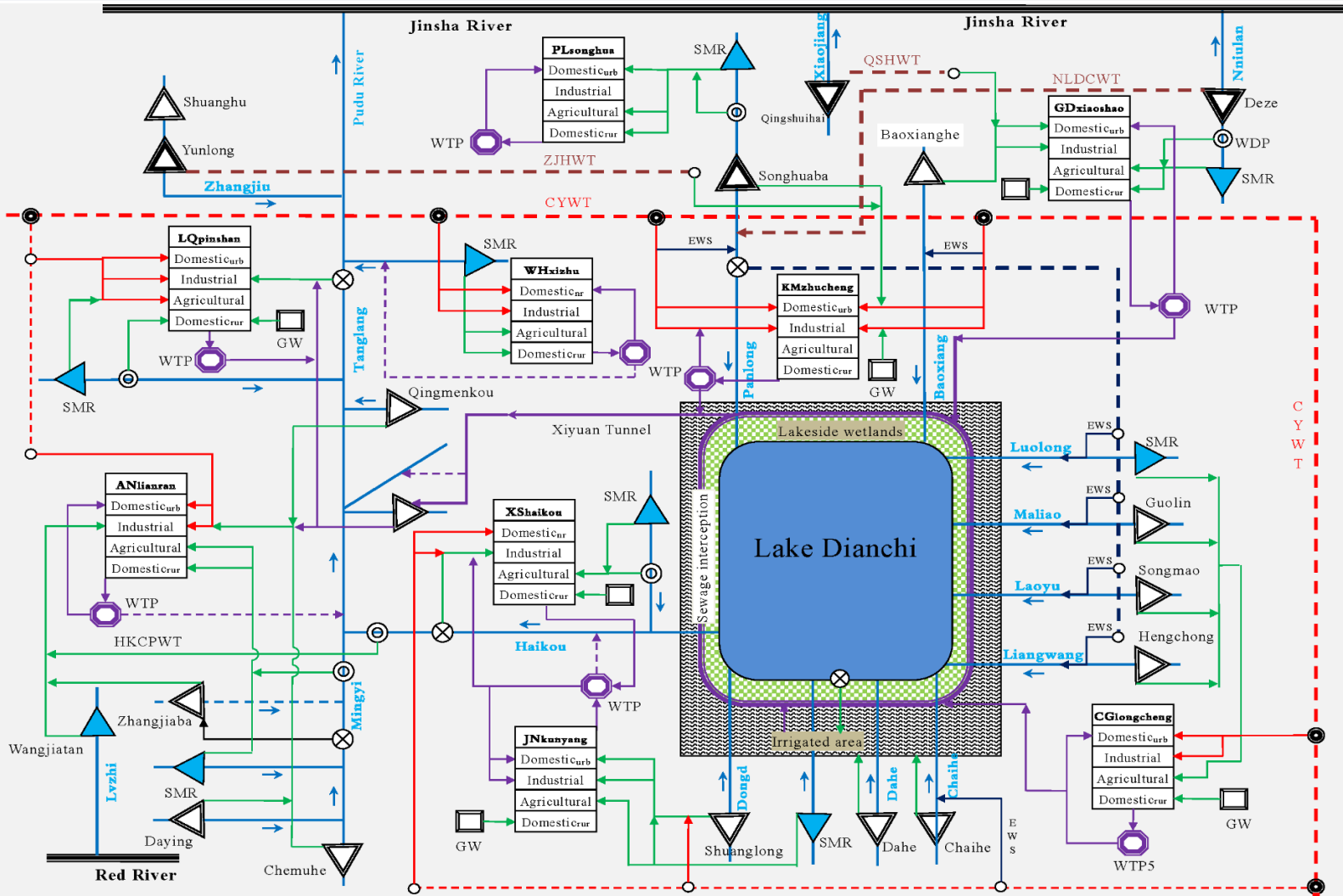


Fig.3 Conceptual network diagram for water resources system in Lake Dianchi basin and its associated regions

3 Results and discussion

3.1 Urban and rural water supply security scheme

The water supply of local water sources is 505 million m^3 in 2015 (Table 2), and the degree of water resources exploitation and utilization is up to 91.0%. The proportion of water transfer for urban water supply will gradually increase from 44.9% (2015) to 66.8% (2030). In accordance with the principle of "ecological priority", the ecological water of rivers is gradually returned through reservoir ecological operation, and the proportion of local water used to ensure the ecological water has increased from 9.0% (2015) to 33.2% (2030), which roughly guarantees the ecological baseflows of rivers flowing into the lake.

Table 2 Demand-supply balance of water resources in Lake Dianchi basin and its associated regions

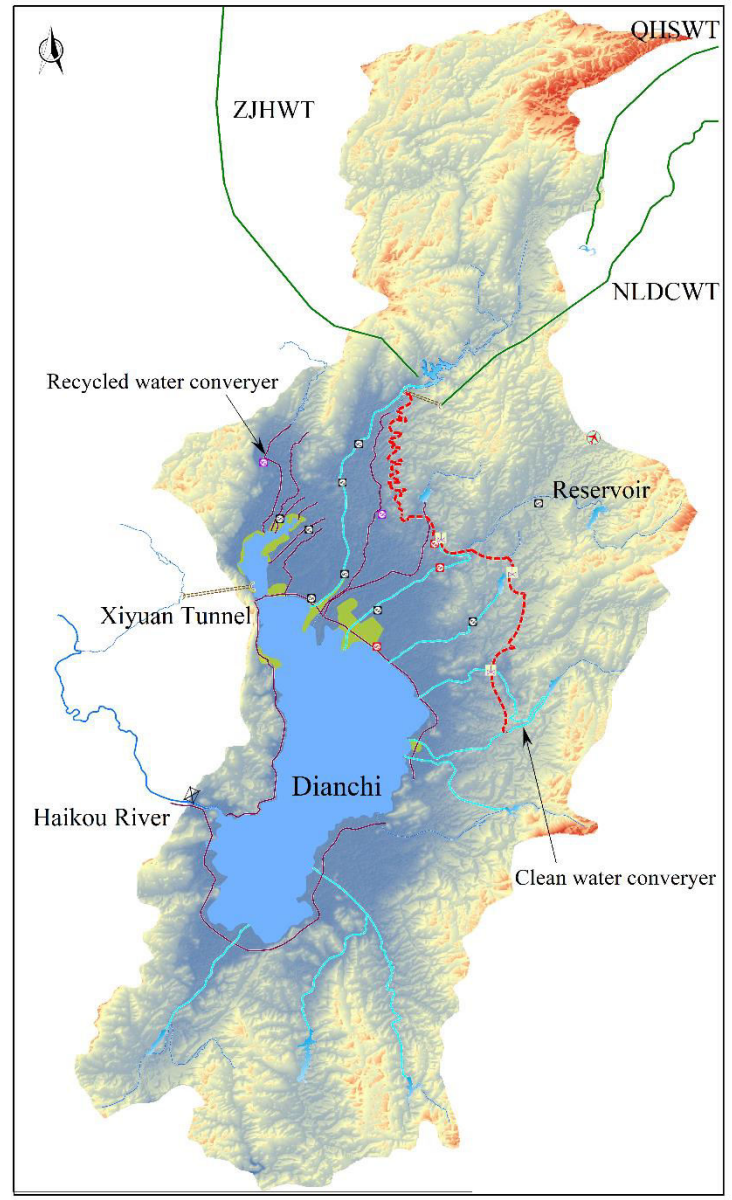
Subregion	Target year	Demand (10^8 m^3)				Supply (10^8 m^3)								Deficient ratio (%)
		Dom.	Ind.	Agri.	Total	Local sources				WT sources		WTP	Total	
						WSE	WDP	WPP	GW	SWT	CYWT			
Lake Dianchi Basin	2015	3.54	2.58	2.34	8.46	2.76	0.22	1.42	0.71	2.75	0.00	0.34	8.20	3.1
	2020	4.42	2.55	2.00	8.97	2.66	0.19	1.59	0.58	3.27	0.00	0.55	8.83	1.5
	2030	5.28	2.67	1.87	9.82	2.33	0.11	1.04	0.22	1.09	4.22	0.72	9.74	0.8
Anning-Fumin corridor	2015	0.45	1.88	1.28	3.60	1.30	0.28	1.51	0.46	0.00	0.00	0.00	3.56	1.1
	2020	0.63	4.23	1.42	6.28	1.94	2.29	0.76	0.02	0.00	0.00	1.14	6.16	1.9
	2030	0.87	5.60	1.58	8.05	1.39	0.23	0.48	0.02	0.00	4.42	1.44	7.99	0.8

3 Results and discussion

3.2 Ecological water dispatching scheme

The ecological water requirements of some rivers has been satisfied through the reservoir ecological operation, but the Panlong River, Luolong River, Ma Yue River, Lao Yu River, Liangwang River and other rivers in the east and north of Kunming city pass through the city, and the corridor landscape requires a large amount of water, which is difficult to meet the ecological water demand of these rivers through the reservoir ecological operation.

It is planned to construct a new river network connecting project (Fig. 5), which will allocate 268.7 million m^3 of ecological water to the above-mentioned rivers. The length of the clear water corridor reaches 455.0km, accounting for 77.3% of the total. Meanwhile, the water quality of the rivers is Class III (consistent with that of NLDCWT), reaching the water quality target of water function zoning in 2030. It is of great significance for the continuous improvement of the water quality of Dianchi Lake to ensure clean water into the lake and restore the mechanism of clean water flow in the basin under the cooperation of the river comprehensive regulation project and the wetland around the lake.



3.3 Sewage load reduction and resource recycling scheme

Affected by the optimized industrial layout and the imperfect supporting pipe network, the reuse rate of reclaimed water in the basin is still relatively low.

In the future, the industry of Kunming will be mainly distributed in the AFIC, and the demand for reclaimed water is mainly concentrated in the lower reaches of Dianchi Lake. Therefore, inter-regional allocation of recycled is adopted to improve the reuse rate of recycled water.

According to the local industrial development plan, it is predicted that the industrial water demand of the AFIC will be as high as 423 million m^3. The circulating cooling water, steel smelting and other industries can use recycled water. The demand of recycled water is 114 million m^3, excluding the amount of recycled water in the AFIC of 11 million m^3. Therefore, 103 million m^3 of recycled water discharged from the Dianchi Basin can be deployed to the AFIC.

On the other hand, the reclaimed water in the Dianchi Lake basin will be 415 million m^3, where the municipal water consumption will be 55 million m^3, and the ecological water replenishment consumption will be 60 million m^3 (water evaporation from the surface). With 103 million m^3 of resource utilization, the reclaimed water reuse rate in Dianchi Lake basin will reach 39.5%, close to developed countries' reuse level.

3 Results and discussion

3.3 Sewage load reduction and resource recycling scheme

Previous studies have shown that reducing the pollution load into the lake during the post-NLDCWT period is the fundamental way to improve the lake water quality (Liu et al. 2014). On the premise of maintaining the lake water balance, it is an effective way to reduce the pollution load into the lake by discharging the reclaimed water through the Xiyuan tunnel as far as possible. In this paper, three scenarios are proposed to determine the amount of reclaimed water discharged outside the basin: 1) all discharged outside (AD); 2) On-demand discharged outside (OD); and 3) All into the lake(AI). The simulation results of water balance components and lake level in each scheme are shown in Table 2.

Table 2 Water balance of Lake Dianchi under different scenarios in 2020 target year of planning

Scheme	Water input ($10^8 m^3$)						Water output ($10^8 m^3$)				Water level (m)		ΔV ($10^8 m^3$)	Filling up rate (%)
	I_p	I_b	I_c	I_{sa}	I_{su}	Total	O_E	O_{ET}	O_R	Total	mean	minimum		
AD	2.83	5.68	5.39	0.58	0.00	14.48	4.52	1.78	8.16	14.46	1887.12	1886.10	0.02	34.08
OD	2.83	5.68	5.39	0.58	2.51	16.99	4.52	1.78	10.67	16.97	1887.15	1886.11	0.02	35.12
AI	2.83	5.68	5.39	0.58	3.54	18.02	4.52	1.78	11.70	18.00	1887.17	1886.14	0.02	37.20

3 Results and discussion

3.3 Sewage load reduction and resource recycling scheme

Three indicators, i.e., the mean level, the minimum level, and the lake filling rate, are used to determine the optional scheme. As seen from Table 3, because the reclaimed water is relatively uniform, it has little influence on the lake water level. In the AD scheme, the mean lake level is 1887.12m, the minimum lake level is 1886.10m, the filling rate is 34.08%, the water level fluctuates near the flood control level, and the monthly water level of 90.8% fluctuates periodically between 1886.70m and 1887.50m (see Figure 5).

The AD scheme is conducive to improving lake water quality and managing wetlands around the lake. Under the premise of ecological water replenishment of 566 million m^3 by the NLDCWT project, all reclaimed water in the basin will not enter the lake, which can significantly reduce the pollution load into the lake.

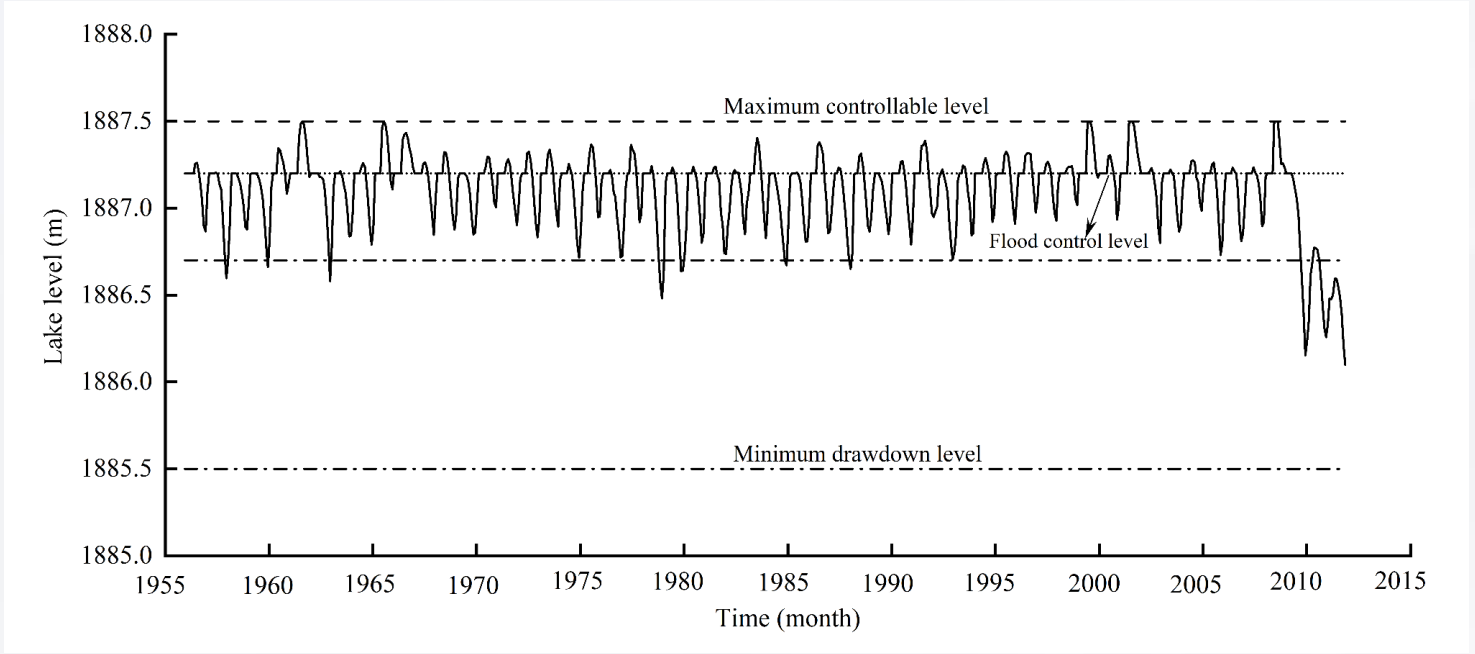


Figure 5 Simulated results of water level of Lake Dianchi

4 Conclusions

1. The key to reconstructing the healthy water cycle in Dianchi Lake basin is to clarify the disordered river and lake functions and determine the clear water corridor and the recycled water channel at the basin scale. Classification management should be strictly implemented according to the functions of various rivers in the future river management.

2. Guaranteeing river ecological water is the critical task of river ecological restoration in the studied basin. This paper guarantees ecological water of into-lake rivers by three ways: upstream reservoir ecological operation, connected river network replenishment, and reclaimed water replenishment. The total length of the clear water corridor accounts for 70.3% of the total. In combination with the river regulation project, the clean water channel will be built to ensure that the water quality is not lower than Class III. That is, the water quality target of water function zoning in 2030 will be reached in advance.

3. To reduce the pollution load into the lake, the recycled water should be discharged directly outside the basin as far as possible, and the outflow depends on the lake water balance. Before the water transfer project is implemented, the recycled water had to be discharged into the lake to maintain its water balance. Under the premise that NLDCWT project has supplied multi-year average of 572 million m^3 freshwater, Dianchi Lake has been able to maintain water balance by relying on clean water. All the recycled water may be deployed towards the downstream AFIC as industrial water.