

Analysis on the Trend of Total Water Use and Water Use Efficiency in the Pearl River Basin During 2001-2017

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Keywords: Water Resources Management, Pearl River Basin, The Most Stringent Water Management Policy.

Abstract: Implementing the most stringent water management policy (MSWMP), which includes total water use redline, water use efficiency redline and pollution limit redline, is the guiding principle and overall requirement for water resources management in China. In recent years, through the implementation of the MSWMP, the water resources management system and capability have been gradually improved, and water resources management has achieved remarkable results. Based on the data released from the 2001-2017 Water Resources Bulletin of Pearl River Basin, this paper systematically analyzes the total water use and main water use efficiency indicators of the water resources secondary area and provincial administrative area in the basin, and the trend of it also been revealed. In summary, this study aims to provide the watershed management agency with a reference for the better implementation of the MSWMP in the future.

1 INTRODUCTION

Water is one of the basic resources for social and economic development. From the perspective of China's historical development process, the water resources development and utilization mode has gradually shifted from extensive high-water consumption and high pollution mode to water-saving priority sustainable development mode. In order to better promote the rational, orderly and sustainable development and utilization of regional water resources (Wang, 2015; Liu, 2012; Men, 2018), the state has put forward the most stringent water resources management system, formulated an insurmountable red line for the total water use and water use efficiency of regional socio-economic development, and prioritized water conservation and building a water-saving society as the clearly defined central water management policy of the 18th Party Congress (Yong, 2015). In order to better promote the implementation of the most stringent water resources management system (Zuo, 2014), it is necessary to explore the relatively weak links in regional water resources management, and to study the changes in the historical development trends of total water use and water use efficiency in river basins and regions.

The Pearl River is the second largest river in China. Its annual runoff ranks second in the national river system, with a total length of 2320 km. The Pearl River includes the three major tributaries of Xijiang River, Beijiang River and Dongjiang River, and flows through the provinces (districts) of Yunnan, Guizhou, Guangxi, Guangdong, Hunan and Jiangxi. In addition to the Pearl River Basin, the Pearl River Area includes rivers along the coast of South China and rivers in Hainan Island.

Based on the data of Water Resources Bulletin of the Pearl River Area from 2001 to 2017, this paper analyzes and summarizes the changing trend of the total water use and main water use efficiency indicators of the secondary water resources areas and provincial administrative regions in the Pearl River Area, and points out the relatively weak links in the water resources management of the river basins, which has certain reference value for watershed and regional water resources management.

2 OVERVIEW OF THE PEARL RIVER AREA

2.1 Water Resources Component

The Pearl River Area includes the Pearl River Basin, the Hanjiang River Basin, the coastal rivers of Guangdong and Guangxi, and the rivers in Hainan Province. Among them, the Hanjiang River Basin, coastal rivers of Guangdong and Guangxi, and the rivers in Hainan Province are jointly called the Coastal Rivers of South China. The whole river system is divided into 10 secondary water resources areas, including North and South Panjiang River (NSPJ), Hongliujiang River (HLJ), Yujiang River (YJ), Xijiang River (XJ), Beijiang River (BJ), Dongjiang River (DJ), Pearl River Delta, Hanjiang and eastern Guangdong Rivers (HGRs), Coastal Rivers of West Guangdong and South Guangxi (GGCRs), Rivers in Hainan and South China Sea Islands (SCIRs), of which the HLJ has a maximum area of 113,000 km² and Pearl River Delta has a minimum area of 27,000 km². According to administrative division, the river system involves 8 provinces (or autonomous regions) of Yunnan, Guizhou, Guangxi, Guangdong, Hunan, Jiangxi, Fujian and Hainan, and two special administrative regions of Hong Kong and Macao.

2.2 Precipitation

The average annual precipitation of the Pearl River Area is $8948.5 \times 10^8 \text{ m}^3$ (1956-2000 series, based on the evaluation results of the second national water resources investigation), which is equivalent to a depth of 1549 mm. In comparison, the average precipitation from 2001 to 2017 is $9071.9 \times 10^8 \text{ m}^3$, which is equivalent to a depth of 1570 mm. The overall difference is only about 1.4%. Generally, the average precipitation in the Pearl River Area in recent 17 years is close to the perennial average value, but the average precipitation in some secondary water resources areas and administrative regions in recent 15 years is quite different from the perennial average value (table 1). Among them, the average precipitation in the NSPJ area in recent 17 years is 8.5% less than the perennial average value, and the average precipitation in Hainan Island in recent 15 years is 12.9% more than the perennial average value. There is a great difference between the average precipitation in recent 17 years and the perennial average value in each province (table 2). For example, the average precipitation in Yunnan and

Guizhou provinces has decreased, while that in Hainan has increased. The deviation is more than 5%.

Table 1: Comparison of average precipitation from 2001 to 2017 and perennial value for secondary water resources areas within the Pearl River Area.

Secondary water resources areas	Average precipitation from 2001 to 2017 (10^8 m^3)	Perennial value (10^8 m^3)	Deviation ratio
NSPJ	862.7	943.3	-8.5%
HLJ	1645.1	1664.1	-1.1%
YJ	1035.3	1028.8	0.6%
XJ	1122.5	1081.2	3.8%
BJ	849.5	829.4	2.4%
DJ	472.7	471.9	0.2%
Pearl River Delta	505.8	492.2	2.8%
HGRs	809.7	793.1	2.1%
GGCRs	1093.8	1047.0	4.5%
SCIRs	674.8	597.4	12.9%

Note: The perennial value in this paper refers to the series from 1956 to 2000, which is based on the evaluation results of the second national water resources investigation.

Table 2: Comparison of average precipitation from 2001 to 2017 and perennial value for provincial administrative regions within the Pearl River Area.

Administrative regions	Average precipitation from 2001 to 2017 (10^8 m^3)	Perennial value (10^8 m^3)	Deviation ratio
Yunnan	557.3	625.0	-10.8%
Guizhou	721.5	773.2	-6.7%
Guangxi	3557.5	3468.8	2.6%
Guangdong	3216.1	3139.5	2.4%
Hainan	674.8	597.4	12.9%
Fujian	207.5	204.7	1.4%
Hunan	77.6	80.3	-3.3%
Jiangxi	59.6	59.6	0.0%

2.3 Water Resources Amount

The average annual runoff in the Pearl River Area is $4708.5 \times 10^8 \text{ m}^3$, which is equivalent to 815 mm in depth. As for the secondary water resources areas: $390 \times 10^8 \text{ m}^3$ in NSPJ, $904 \times 10^8 \text{ m}^3$ in HLJ, $424 \times 10^8 \text{ m}^3$ in YJ, $583 \times 10^8 \text{ m}^3$ in XJ, $510 \times 10^8 \text{ m}^3$ in BJ,

510×10⁸ m³ in DJ, 281×10⁸ m³ in Pearl River Delta, 458×10⁸ m³ in HGRs, 581×10⁸ m³ in GGCRs, and 304×10⁸ m³ in SCIRs. By administrative division (refers only to the provincial administrative regions within the Pearl River Area), the average annual runoff is: 229×10⁸ m³ in Yunnan Province, 382×10⁸ m³ in Guizhou Province, 1780×10⁸ m³ in Guangxi Province, 1817×10⁸ m³ in Guangdong Province, 304×10⁸ m³ in Hainan Province, 116×10⁸ m³ in Fujian Province, 48×10⁸ m³ in Hunan Province, 32×10⁸ m³ in Jiangxi Province.

From 2001 to 2017, the average water resources amount in the Pearl River Area was 4842×10⁸ m³ and the equivalent runoff depth was 838 mm, which was

similar to the 1956-2000 series. However, there were some differences in water resources amount among the sub-regions. The amount of water resources in each sub-region from 2001 to 2017 was compared with the perennial average value, and the number of wet, normal and dry years in recent 17 years was counted. The results of the division by secondary water resources areas and provinces are shown in table 3 and table 4, respectively.

It can be seen that the difference in water resources amount between the 17-year series mean and the perennial value in each sub-region is related to the number of wet, normal and dry years. There are more dry and extra-dry years in NSPJ basin, Yunnan and Guizhou provinces, and more wet and extra-wet years in XJ basin and Hainan Island.

Table 3: Comparison of average water resources amount from 2001 to 2017 and perennial value for secondary water resources areas within the Pearl River Area, and the statistics on Wet-dry of runoff series.

Secondary water resources areas	Average value of 2001-2017 (10 ⁸ m ³)	Perennial value of 1956-2000 (10 ⁸ m ³)	Deviation ratio	Extreme wet	wet	normal	dry	Extreme dry
NSPJ	326	390	-16.5%	0	1	6	3	7
HLJ	902	904	-0.3%	3	2	6	4	2
YJ	418	424	-1.3%	3	2	4	4	4
XJ	661	583	13.2%	7	4	4	0	2
BJ	528	510	3.4%	3	5	4	3	2
DJ	271	274	-1.1%	3	2	6	1	5
PRD	292	281	4.1%	5	2	6	2	2
HGRs	475	458	3.9%	4	2	6	2	3
GGCRs	602	581	3.6%	4	3	5	2	3
SCIRs	368	304	21.1%	9	1	4	0	3

Table 4: Comparison of average water resources amount from 2001 to 2017 and perennial value for administrative regions within the Pearl River Area, and the statistics on Wet-dry of runoff series.

Administrative regions	Average value of 2001-2017 (10 ⁸ m ³)	Perennial value of 1956-2000 (10 ⁸ m ³)	Deviation ratio	Extreme wet	wet	normal	dry	Extreme dry
Yunnan	194	229	-15.3%	1	1	4	4	7
Guizhou	355	382	-7.2%	1	1	8	5	2
Guangxi	1860	1780	4.5%	5	2	6	1	3
Guangdong	1865	1817	2.6%	5	1	6	4	1
Hainan	368	304	21.1%	9	1	4	0	3
Fujian	119	116	2.6%	5	1	6	0	5
Hunan	50	48	2.5%	4	2	4	5	2
Jiangxi	32	32	1.3%	3	2	7	0	5

3 ANALYSIS OF TOTAL WATER USE AND ITS TREND

From 2001 to 2017, the average total water supply and consumption in the Pearl River Area was $861.5 \times 10^8 \text{ m}^3$, and the total water use in the basin area increased first and then decreased (figure 1). The total amount of water supply and consumption in the Pearl River Area from 2001 to 2017 is shown in table 5.

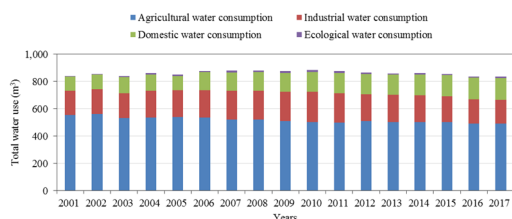


Figure 1: Schematic diagram of total water use in the Pearl River Area from 2001 to 2017.

Table 5: Total water use in the Pearl River Area from 2001 to 2017.

Years	Total water supply and consumption (10^8 m^3)	Years	Total water supply and consumption (10^8 m^3)
2001	838.2	2010	883.4
2002	851.9	2011	877.8
2003	840.1	2012	864.8
2004	861.1	2013	859.3
2005	873.6	2014	861.6
2006	878.9	2015	857.2
2007	879.9	2016	838.1
2008	881.2	2017	836.2
2009	876.8	Average	861.5

From the perspective of secondary water resources areas: the total amounts of water use in XJ area, Pearl River Delta area, HLJ area and DJ area generally show the trend of rising first and then falling; BJ area shows a trend of slow decline; YJ area shows an obvious upward trend in water use in the early stage, and water use has been relatively stable in the past 10 years; the total water use in GGCRs and SCIRs areas is relatively stable; and the total water use in HGRs shows a slow upward trend as a whole.

From the perspective of provincial administrative regions, the total amounts of water use in Guangdong, Yunnan and Guizhou provinces have generally increased first and then decreased. Among

them, Guangdong and Yunnan provinces have seen a significant decline since 2011; the peak water consumption in Guizhou Province appeared in 2010, and the downward trend after 2012 is more obvious; the total water consumption in Guangxi Autonomous Region has generally increased first and then decreased, and the downward trend is slower; the total water consumption in Fujian and Jiangxi provinces showed a slow upward trend; and the total water consumption in Hunan Province was relatively stable.

4 ANALYSIS OF WATER EFFICIENCY INDICATORS

4.1 Per Capita Comprehensive Water Consumption

Since 2001, the per capita water consumption in the Pearl River Area has generally declined (figure 2). The average per capita comprehensive water consumption of the basin area has decreased from 547 m^3 in 2001 to 434 m^3 in 2017. On the one hand, the total water use in the basin area has generally declined slowly. On the other hand, the population in the basin area has grown rapidly. Water use indicators for some years in the basin area are shown in table 6.

From the perspective of secondary water resources areas: the per capita comprehensive water consumption indicators of NSPJ area, XJ area, HGRs area, and GGCRs area have generally changed little; the per capita comprehensive water consumption indicators of HLJ area and YJ area have increased to a certain extent; the per capita comprehensive water consumption indicators of BJ area, DJ area, Pearl River Delta area, and SCIRs area have declined significantly.

From the perspective of provincial administrative regions, the per capita comprehensive water consumption in Yunnan, Guangdong, Hainan and Hunan provinces showed a downward trend; the per capita comprehensive water consumption in Guizhou, Guangxi, Fujian and Jiangxi provinces showed an upward trend.

According to the indicators of 2017, the per capita comprehensive water consumption in HLJ area, YJ area, XJ area and BJ area is higher than 500 m^3 , while the per capita comprehensive water consumption in NSPJ area, DJ area and Pearl River Delta area is lower than 400 m^3 . Among the provinces and regions, the per capita comprehensive water consumption of Guangxi and Fujian is relatively high,

with Fujian reaching 734 m³, while Yunnan and Guizhou have relatively low indicators.

Table 6: Changes in the per capita comprehensive water consumption indicators in the Pearl River Area (m³).

Water resources areas or administrative regions	2001	2005	2010	2015	2017
NSPJ	282	277	271	286	291
HLJ	505	570	558	600	554
YJ	512	530	622	607	576
XJ	617	675	662	606	559
BJ	626	618	585	552	542
DJ	623	481	446	365	344
Pearl River Delta	988	554	441	393	365
HGRs	374	364	399	366	354
GGCRs	483	490	490	476	474
SCIRs	566	538	511	503	492
The Pearl River Area	547	505	480	455	434
Yunnan	334	315	257	279	284
Guizhou	217	213	259	295	323
Guangxi	595	625	647	618	577
Guangdong	589	499	449	408	388
Hainan	566	538	511	503	492
Fujian	707	621	1181	811	734
Hunan	520	360	429	413	423
Jiangxi	289	317	293	476	485

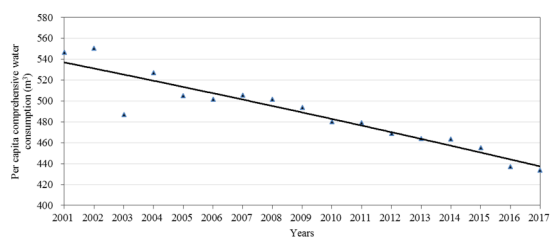


Figure 2: Schematic diagram of the trend of per capita comprehensive water consumption in the Pearl River Area from 2001 to 2017.

4.2 Water Consumption per 10,000 Yuan of GDP

From the overall perspective of the basin area, the water consumption per 10,000 yuan of GDP showed a significant downward trend from 2001 to 2017. The average value of water consumption per 10,000 yuan

of GDP in the basin area was 522 m³ in 2001 and decreased to 64 m³ in 2017 (table 7). The changing trend of water consumption per 10,000 yuan of GDP in the Pearl River Area from 2001 to 2017 is shown in figure 3.

From the perspective of secondary water resources areas, the water consumption per 10,000 yuan of GDP in the 10 secondary water resources areas within the Pearl River Area has been greatly reduced. In terms of absolute value of the indicators, the water consumption per 10,000 yuan of GDP in Pearl River Delta area is far less than that of other water resources areas in the same year, which reflects the remarkable effect of water saving work in the water resources areas.

From the perspective of provincial administrative regions, the water consumption per 10,000 yuan of GDP in 8 provinces and regions within the Pearl River Area has been greatly reduced. In terms of absolute value of the indicators, the water consumption per 10,000 yuan of GDP in Guangdong Province is far less than that in other provinces and regions, followed by Yunnan and Guizhou, while the water consumption per 10,000 yuan of GDP in the area of Jiangxi Province within the Pearl River Area is the highest due to the large proportion of agriculture.

From the perspective of indicators in 2017, among the secondary water resources areas, the water consumption per 10,000 yuan of GDP in HLJ area, YJ area and XJ area is relatively high, while the water consumption per 10,000 yuan of GDP in DJ area and Pearl River Deltas area is relatively low. From the perspective of provincial administrative regions, the water consumption per 10,000 yuan of GDP of Jiangxi Province is the highest, while that of Guangdong Province is the lowest.

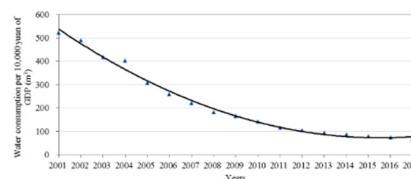


Figure 3: Schematic diagram of the changing trend of water consumption per 10,000 yuan of GDP in the Pearl River Area from 2001 to 2017.

Table 7: Changes in the water consumption per 10,000 yuan of GDP in the Pearl River Area (m³).

Water resources areas or administrative regions	2001	2005	2010	2015	2017
NSPJ	528	324	168	82	73
HLJ	1214	789	311	189	147
YJ	992	625	291	150	119
XJ	1035	780	337	189	153
BJ	1068	659	225	140	119
DJ	333	183	100	50	37
Pearl River Delta	249	133	61	34	28
HGRs	556	398	197	111	89
GGCRs	739	501	225	126	100
SCIRs	787	487	216	124	102
The Pearl River Area	522	307	141	80	64
Yunnan	460	304	138	83	75
Guizhou	822	437	252	92	86
Guangxi	1206	763	313	175	136
Guangdong	368	211	99	56	45
Hainan	787	487	216	124	102
Fujian	1158	638	310	125	92
Hunan	1370	503	374	145	121
Jiangxi	991	634	269	225	187

4.3 Water Consumption per Mu

From 2001 to 2017, the average gross water consumption per mu (a unit of area, equals to 0.0667 hectares) in the basin area showed a downward trend. The fluctuation between years mainly came from the influence of annual precipitation. The decrease of the average water consumption per mu was generally due to the improvement of water saving level in agriculture and the increase of irrigation coefficient of farmland water year by year. Because of the difference of regional climate conditions and planting structure, the horizontal comparability of water use per mu between different water resources areas and administrative regions is not high, so no comparison is made. The variation trend of water consumption per mu in the Pearl River Area from 2001 to 2017 is shown in figure 4. The specific statistics are shown in table 8.

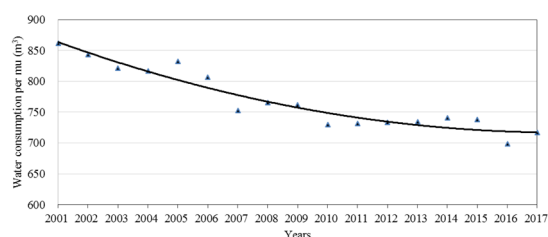


Figure 4: Schematic diagram of the changing trend of water consumption per mu in the Pearl River Area from 2001 to 2017.

 Table 8: Changes in the water consumption per Mu in the Pearl River Area (m³).

Basis of division	Water resources areas or administrative regions	2001	2005	2010	2015	2017
Secondary water resources areas	NSPJ	520	533	360	359	357
	HLJ	849	922	757	728	691
	YJ	921	949	838	793	721
	XJ	973	1003	966	864	825
	BJ	809	777	709	689	708
	DJ	972	825	740	756	747
	Pearl River Delta	800	815	632	724	741
	HGRs	893	841	793	749	752
	GGCRs	897	868	818	818	786
	SCIRs	1033	618	552	995	1000
Administrative regions	The Pearl River Area	862	832	730	738	717
	Yunnan	487	507	308	333	330
	Guizhou	585	601	480	399	398
	Guangxi	995	1042	907	869	807
	Guangdong	834	803	751	753	756
	Hainan	1033	618	552	995	1000
	Fujian	938	759	725	652	639
	Hunan	713	557	504	532	517
	Jiangxi	468	531	413	522	564

4.4 Water Consumption of Industrial Added Value per 10,000 Yuan

From 2001 to 2017, the industrial added value per 10,000 yuan in the Pearl River Area decreased substantially, mainly benefiting from the guidance of the national industrial policy and the gradual withdrawal of high water consumption and high pollution industries gradually. Meanwhile, the water consumption per unit product was also decreasing due to technological progress. The changing trend of water consumption of industrial added value per

10,000 yuan in the Pearl River Area from 2001 to 2017 is shown in figure 5. The specific statistics are shown in table 9.

Judging from the situation of the secondary water resources areas, the water consumption of industrial added value per 10,000 yuan has been greatly reduced. The water consumption of industrial added value per 10,000 yuan in DJ area, Pearl River Delta area, and GGCRs area has been reduced to less than 40 m³ in 2017. Although the indicators in HLJ area and YJ area have also been greatly reduced, the water consumption of industrial added value per 10,000 yuan in 2017 is still around 70 m³, which has not yet fallen to the average level of the basin area in 2011. Relevant areas should strengthen industrial policy guidance, adjust regional industrial structure, strengthen technological transformation, improve water use efficiency and reduce water consumption intensity.

From the perspective of provincial administrative regions, in 2017, the water consumption of industrial added value per 10,000 yuan in Guangdong Province has fallen below 40 m³, and the efficiency of industrial water use is relatively high; while in Fujian, Guizhou, Guangxi and other provinces, the water consumption of industrial added value per 10,000 yuan is still in a relatively high range, which means that there is greater water-saving space and potential.

From the indicators of 2017, among the secondary water resources areas, the water consumption of industrial added value per 10,000 yuan in HLJ area and YJ area is relatively high, while the water consumption of industrial added value per 10,000 yuan in DJ area, Pearl River Delta area, and GGCRs area is lower. From the perspective of provincial administrative regions, Fujian, Guizhou, Guangxi and other provinces have higher water consumption of industrial added value per 10,000 yuan, while the water consumption of industrial added value per 10,000 yuan in Guangdong Province and Yunnan Province is lower.

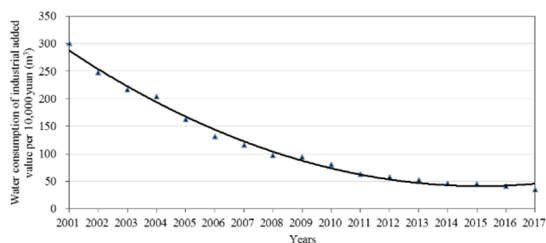


Figure 5: Schematic diagram of the changing trend of water consumption of industrial added value per 10,000 yuan in the Pearl River Area from 2001 to 2017.

Table 9: Changes in the water consumption of industrial added value per 10,000 yuan in the Pearl River Area (m³).

Water resources areas or administrative regions	2001	2005	2010	2015	2017
NSPJ	520	533	360	359	357
HLJ	849	922	757	728	691
YJ	921	949	838	793	721
XJ	973	1003	966	864	825
BJ	809	777	709	689	708
DJ	972	825	740	756	747
Pearl River Delta	800	815	632	724	741
HGRs	893	841	793	749	752
GGCRs	897	868	818	818	786
SCIRs	1033	618	552	995	1000
The Pearl River Area	862	832	730	738	717
Yunnan	241	125	74	39	41
Guizhou	226	351	263	88	68
Guangxi	667	356	148	88	59
Guangdong	202	135	64	35	28
Hainan	378	203	101	67	57
Fujian	520	478	227	102	57
Hunan	510	280	173	66	55
Jiangxi	471	164	78	60	40

5 CONCLUSION

Based on the basic data of the Pearl River Water Resources Bulletin from 2001 to 2017, this paper analyses the precipitation and water resources situation in the basin area in the past 17 years, and the changes of the total water use and some water use efficiency indicators in the secondary water resources areas and provincial administrative regions. This paper summarizes the changing trend of indicators in different areas of the river basin area, which has a certain reference value for better promoting the implementation of the most stringent water resources management system and the improvement of assessment indicators of water resources management in relevant areas.

ACKNOWLEDGMENTS

This research was supported by the Special Foundation for National Science and Technology Basic Research Program of China (2019FY101900), the National Natural Science Foundation of China (5170929) and the Key R&D Program of Guangxi Zhuang Autonomous Region (902229136010).

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