

A study on the characteristics and influencing factors of reservoir sedimentation in Wanjiashai Reservoir

Ren Zhihui^{1,2}, Wang Ting^{1,2}, Wang Yuanjian^{1,2}, Qu Shaojun^{1,2}

¹Yellow River Institute of Hydraulic Research, Zhengzhou 450003, China;

²Key Laboratory of Yellow River Sediment Research, MWR, Zhengzhou 450003, China)

Author: Ren Zhihui (1986-), Female, Weihui, Henan, Engineer, Master's Degree, Specialized in sedimentation and reservoir management.

Wang Yuanjian, Senior Engineer, Doctor's Degree, Specialized in reservoir sediment and river dynamics.

Abstract. Based on measured data of the Wanjiashai Reservoir in different periods, the characteristics of the spatial and temporal distribution of sedimentation in the reservoir area were preliminarily analyzed and the impact of reservoir operation on this distribution was discussed. Primary conclusions are as followed: in terms of temporal distribution, sedimentation continuously accumulated over the period from 2000 to 2017, with the sediment deposition ratio dramatically decreasing between 2011 and 2017; in terms of spatial distribution, the sedimentation in the reservoir area was mainly concentrated downstream of the WD54 section, with the highest concentration being downstream of the WD23 section. The characteristics of sedimentation distribution in the reservoir area were closely related to inflow and sediment conditions and reservoir operation water level. When the water level was lower than 952 m, the sediment deposition ratio was lower than 0. To further improve the sediment deposition form in the reservoir area, lowering water level and ejecting the sediment are recommended in a timely manner.

1 Introduction

Constructing a reservoir on a sandy river changes the inflow and sediment conditions of the natural river, disturbs the relative balance of riverbed configuration, and readjusts the inflow and sediment conditions and riverbed configuration, thereby causing a series problems such as reservoir sediment deposition ^[1], utilizing efficiency and the reservoir operation lifetime decrease ^[2-3], and so on. Reservoir sedimentation distribution characteristics are affected by factors such as the shape of the reservoir area, river bottom gradient in reservoir area, inflow and sediment conditions, weir top elevation of the discharge facilities, and reservoir operation mode ^[3-10]. With regards to the Wanjiashai Reservoir of the Yellow River, researchers have conducted a considerable amount of research work related to sedimentation during both the feasibility and the operation phase of the project, providing important technological support for its scientific operation ^[11-13]. As the operation mode change of the Wanjiashai Reservoir over different operation periods, the reservoir sedimentation presented different characteristics. By analyzing the changes in sedimentation and the longitudinal sections and cross sections of the reservoir area in the period of 2000–2010, Cheng Lijun et al. ^[14] concluded that the sediment deposition formed a delta shape in longitudinal direction below 966 m, with the tail section of the reservoir area obviously scoured in recent years. By analyzing the

sediment scour and deposition conditions of the reservoir in the operation period of up to the flood season of 2005, Lu Zongpan et al. ^[15] proposed that sedimentation occurred in the 0–56.6 km area in front of the dam, and slight scouring occurred from 56.6 to 72.3 km at the tail of the reservoir area. In terms of researches of the factors affecting sediment scour and deposition in the reservoir area, Ren Hongjun et al. ^[16] studied the effect of the reservoir operation mode on sediment deposition during the preliminary operation period; Lin Xiuzhi et al. ^[17] analyzed the influence of the reservoir operation mode on the sedimentation feature in the Wanjiashai Reservoir during the spring flood testing period, and found that a proper water level raise before spring flood period did not increase the sediment deposition in the tail section of the reservoir area.

Based on measured data, the characteristics of the spatial and temporal distribution of sedimentation in the Wanjiashai Reservoir were analyzed. The factors that significantly influence the reservoir sediment deposition were discussed in this paper. Preliminary suggestions were offered to improve sediment deposition conditions in the reservoir area.

2 Background and data

*Corresponding Author: E-mail: wangyuanjian@hky.yrcc.gov.cn E-mail: zhihui2010@126.com

2.1 Wanjiashai Reservoir overview

Wanjiashai water multi-purpose dam project is located in the upper part of the middle section of the Yellow River, with Pianguan County, Shanxi Province, on the left bank of the dam site, and Jungar Banner, Inner Mongolia, on the right bank [18]. The Wanjiashai Reservoir started operating in October 1998; by the end of 2000, all six generator units had been constructed and put into production, during which the operation water level was low and the reservoir water level fluctuated substantially. The normal water level is 977 m, the maximum operation water level is 980 m, and the original reservoir capacity is 896 million m³.

The Wanjiashai Reservoir is a canyon shaped reservoir. It is very narrow and has multiple curves and a large gradient, with U shape for most of the sections. The average width of the surface of the reservoir is around 350 m. The end point of the reservoir backwater is Guaishang, where the longitudinal gradient becomes sharp. The reach between Toudaoguai and Guaishang is a transitional section where the plain type river changes to the mountain type river. The reservoir area is below Guaishang, which is 72 km long and a narrow, mountainous river with a large gradient that has an average natural gradient of 1.17%.

The amount of inflow and sediment from the tributary of Wanjiashai Reservoir area is relatively small, and it is generally considered that inflow and sediment at Toudaoguai hydrological station could represent that into Wanjiashai Reservoir. The downstream control station is Wanjiashai hydrological station. In addition, 73 cross sections have been arranged for the main stream and 16 cross sections for the tributaries to monitor the topographical changes in the reservoir area.

2.2 Data

The inflow and sediment data of Toudaoguai and Wanjiashai hydrological stations were collected from the “Yellow River Basin Hydrological Data” with the period from 2000 to 2017. The terrain data primarily were collected from the technical reports on the reservoir area sedimentation tests of the Yellow River Wanjiashai water multipurpose dam project, which included the topography of 89 sections of the reservoir area from 2000 to 2017 and reservoir capacity data from September 1999

to October 2017. Monthly average water levels from 1999 to 2001 and daily average values from 2002–2017 were also collected.

3 Spatial and temporal characteristics of sedimentation distribution in the reservoir area

In the preliminary operation period of the Wanjiashai Reservoir, inflow was relatively less than normal, and the amount of sediment into the reservoir was relatively less. From 1999 to 2010, average annual inflow at Toudaoguai was 15.15 billion m³, only 78.9% of the designed value. Average annual sediment discharge into the reservoir was 46.1 million tons, only 38.5% of the designed value. Therefore, the actual situation of the reservoir area differed quite significantly from what was originally designed, and as the water level of the reservoir was kept at a slightly higher than previously designed, the sediment-flushing plans were not carried out properly, leading to rapid reservoir sediment deposition [12]. From September 1999 to October 2010, the sediment deposition volume of the reservoir below 980 m was 358.9 million m³. In order to lower the speed of sediment deposition slowly, sediment flushing operations for six times were performed from 2011 to 2017, effectively removing 43.4 million m³ of reservoir sediment deposition below 980m.

3.1 Temporal distribution of sedimentation in the reservoir area

According to the measured data taken between November 1999 and October 2017 at hydrological stations, sediment volume of scour and deposition from 2000 to 2017 was calculated by sediment transport rate method. Its distributions were shown in Table 1 and Figure 1. It is noted that an operational year was defined from November to next year October. From 2000 to 2017, the amount of sediment deposition was 216.4 million m³ during the flood season, and 204 million m³ during the non-flood season, constituting 51% and 49% of the total volume, respectively.

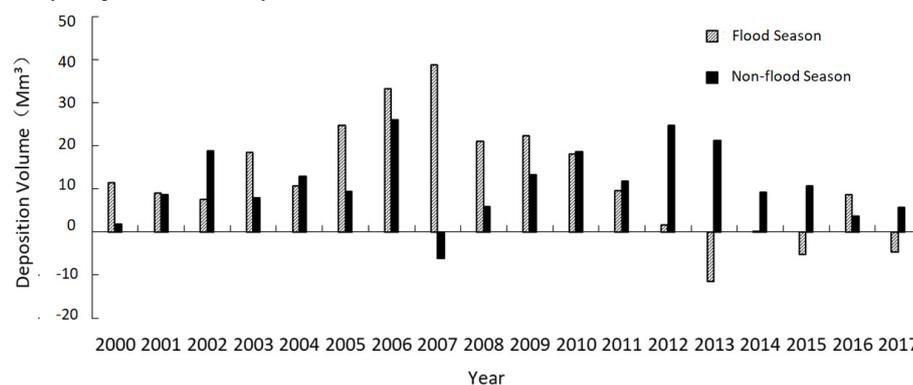


Fig. 1 Map of changes of sediment scour and deposition of the Wanjiashai Reservoir.

Table 1 sediment Amount of scour and deposition and sediment deposition ratio for Wanjiashai Reservoir in different seasons during 2000 to 2017

Year	Sediment into Reservoir	Sediment out Reservoir	sediment Amount			Unti: million t sediment deposition ratio -%-
			Operational year	Flood season	Non-flood season	
2000	29.5	16.1	13.4	11.6	1.8	45.4
2001	18.8	1	17.8	9.2	8.6	94.8
2002	27.2	0.6	26.6	7.7	18.9	97.7
2003	26.7	0.2	26.6	18.7	7.9	99.4
2004	24.7	0.9	23.8	10.9	12.9	96.2
2005	36.4	2.1	34.3	24.8	9.5	94.3
2006	67.4	8.1	59.3	33.3	26	88.0
2007	65.2	32.4	32.8	38.9	-6.1	50.3
2008	53.7	26.6	27.1	21.2	5.9	50.4
2009	46.6	10.7	35.9	22.5	13.3	77.0
2010	57.9	21.2	36.7	18.1	18.6	63.4
2011	37.6	16.1	21.5	9.7	11.8	57.1
2012	76	49.6	26.4	1.7	24.7	34.8
2013	61.2	51.3	9.9	-11.3	21.2	16.1
2014	39.6	30	9.6	0.3	9.3	24.2
2015	21.1	15.6	5.5	-5.1	10.7	26.2
2016	16.4	4.1	12.3	8.7	3.6	75.0
2017	17.1	15.9	1.2	-4.5	5.7	6.9
Sum	723	302.5	420.5	216.4	204	58.2

Note: “-” means scouring, same hereinafter.

From the view of the reservoir sediment deposition volume year by year, it is noted that sedimentation continued to deposit in the 18 years between 2000 and 2017. The amount of sediment deposition during 2011 to 2017 was less than that during 2000 to 2010, and Figure 2 showed that the annual sediment deposition ratio significantly decreased (the amount of sediment deposition per unit of sediment into the reservoir, %). From the view of the sedimentation changes during flood seasons in different years, it is noted that sedimentation continued to deposit in flood season from 2000 to 2010. Deposition volume of 38.9 million m³ was the largest in 2007. Since 2011, Deposition volume during the flood season decreased substantially. Except for 2016, scour dominated the reservoir area in flood season from 2013

to 2017.

In the different reservoir operation periods, the sediment deposition ratio during the flood season also changed. Figure 2 shows that, the flood season sediment deposition ratio was above 95% from 2000 to 2010, which indicated that the sediment was almost completely deposited in the reservoir area. From 2011 to 2017, six times of sediment flushing had been executed; the flood season sediment deposition ratio was drastically reduced, dropping to 6.9% in 2017. Reservoir sedimentation demonstrated different distribution characteristics during non-flood season and flood season, as the sedimentation continued to deposit during non-flood seasons except for 2007.

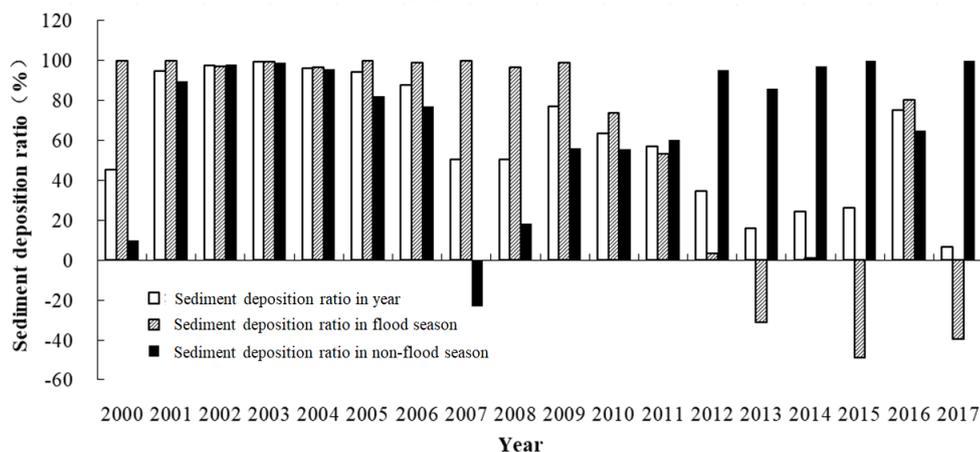


Fig. 2 Changes of the sediment deposition ratio in the Wanjiashai Reservoir from 2000 to 2017.

3.2 Spatial distribution of sedimentation in the reservoir area

Based on the sectional data measured during 2000 to 2017, sediment scour and deposition volumes of different sections in reservoir area were calculated each year. The calculation results showed that the deposition volume of the Wanjiashai Reservoir between 2000 and 2017 was 398.2 million m³, including that above 980m in the reservoir area. The deposition volumes of different reservoir sections, the main stream, and tributaries between 2000 and 2017 are shown in Table 2. Figure 3 shows the spatial sedimentation distributions of different sections in reservoir area during various operational years. From the view of the sedimentation distributions between main stream and the tributaries, sedimentation was mainly deposited at the main stream, as the deposition volume in the main stream alone was 386.1 million m³ between 2000 and 2017, accounting for 97% of total. Figure 3 showed that between 2000 and 2017, the sedimentation was deposited downstream of the WD54 section (55 km away from the dam site), with most sedimentation primarily deposited between the dam and the WD23 section, accounting for 253.3 million m³ of deposition, or 64% of the total. The change of sediment scour and deposition at the tail of the reservoir area from WD54 to WD65 (72 km from the dam) was negligible. The volume of deposition was 3.4 million m³ in this region, only accounting for 0.8% of the total.

In the first two years of reservoir operation, the operation water level was relatively lower, and sedimentation was deposited near the dam site. For example, in 2000, the region between the dam and the WD23 section accumulated 18.6 million m³ of sedimentation, comprising 99% of the yearly deposition that year. As the reservoir operation was continuously adjusted, deposition locations continuously changed, and the distributions of sedimentation across different sections showed different characteristics. Between 2001 and 2013, sedimentation was deposited mainly in the area from the dam to the WD23 section year by year, with sediment volume amounting up to 267.7 million m³. However, from 2014 to 2017, sediment scouring was the major event in that area. Before 2010, the area between the WD23 section and WD54 section mainly demonstrated deposition year by year, followed by scouring between 2011 and 2013, which then changed back to a small amount of deposition in 2014 and 2015. In general, before 2010, the area from the dam to the WD54 section mainly dominated by sediment deposition. From 2011 to 2013, the main event in the area between the dam and WD23 section was deposition, while scour happened in the area between WD23 and WD54 section. It is characterized an upstream scour and downstream deposition feature. And the reservoir Sedimentation feature was adjusted over the years.

Table 2 Sedimentation volumes of Wanjiashai Reservoir survey sections, main stream and tributaries during 2000 to 2017
 Unit: million m³

Operational year	Dam site to WD23		WD23 to WD54		WD54 to WD65		Sum
	Main stream	Tributary	Main stream	Tributary	Main stream	Tributary	
2000	17.1	1.4	1.4	-0.3	-0.1	-0.2	19.4
2001	-0.6	-0.3	18.7	0.4	0.6	0.1	18.8
2002	12.1	-0.7	18.4	-0.3	0.6	-0.1	29.9
2003	18.7	1.1	24.3	0.2	0.3	0.1	44.6
2004	-1.6	-0.6	16.1	0.4	0.6	0	14.9
2005	21.8	0.6	26.8	0.5	0.5	0.1	50.2
2006	48.9	-0.5	12.7	0.3	-1.3	0	60.1
2007	13.8	1.4	18.5	0.6	0.2	0.2	34.6
2008	15.8	0.7	-2.9	-0.1	1.7	0	15.2
2009	13.3	1.1	20	0.5	-1.8	0	33.1
2010	29.7	1.7	-0.9	0.2	0.2	0.1	31.1
2011	26.8	0.8	-10.5	0.2	0.1	0	17.4
2012	27.7	0.5	-15.5	-0.1	-0.7	0	12
2013	16.5	0.6	-3.8	-0.2	-0.6	-0.1	12.4
2014	-16	0.2	6.2	0.4	1.5	0.3	-7.4
2015	-4.6	0.2	3	0	-0.1	0.1	-1.3
2016	10	0.3	8.5	0	0.6	0	19.3
2017	-4.6	0	-2.1	0.2	0.5	0	-6.1
Sum	244.8	8.5	138.8	2.8	2.6	0.8	398.2

Note: The statistics in this table include sedimentation volumes above 980 m elevation in the reservoir.

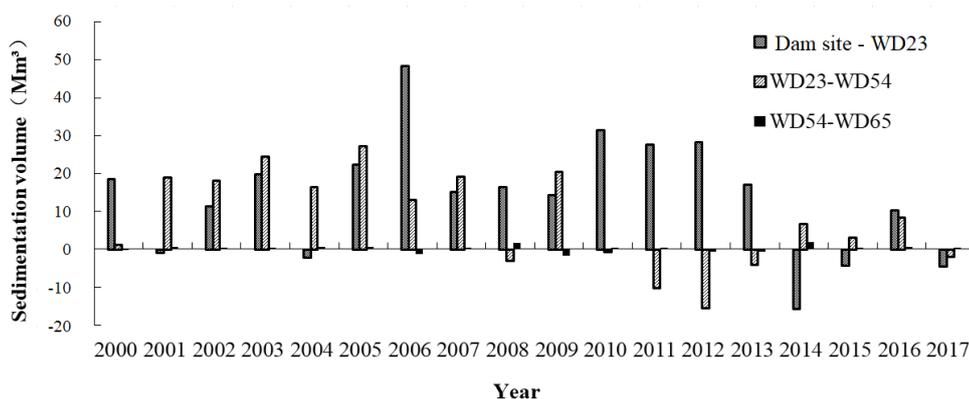


Fig. 3 Spatial distributions of sediment scour and deposition at different sections of the Wanjiashai Reservoir

The elevation distribution of the sedimentation in the reservoir area is closely correlated with the operation water level of the reservoir during the sediment concentration period. Since the sediment into the reservoir mainly arrives during the flood season, the flood control level directly influences the sedimentation

distribution in the reservoir area during the flood season. Based on the statistics of the reservoir capacity from September 1999 to October 2017, the sediment deposition volumes in different elevation regions of the reservoir area were obtained and are listed in Table 3.

Table 3 Sediment deposition volumes in different elevation ranges of Wanjiashai Reservoir from September 1999 to October 2017

Elevation range	Deposition volume -million m ³ -	Elevation range	Deposition volume -million m ³ -
Below 920	26.6	950-955	49.5
920-925	23.2	955-960	41.6
925-930	29.4	960-966	34.7
930-935	35.7	966-970	17.6
935-940	40.5	970-975	14.4
940-945	42	975-979	1.2
945-950	46.9	979-980	-1
Sum			4.023
Below 966m	4.226	Percentage of total (%)	93
966 to 980m	0.322	Percentage of total (%)	7

Table 3 showed that each elevation range produced different degrees of sediment deposition. In particular, the most deposition occurred between 930m and 966 m, with 332.3 million m³ of deposition in this range, comprising 73% of total. Below the flood control level of 966 m, the volume of sedimentation was 422.6 million m³, comprising 93% of total.

4 Analysis of the influencing factors of sedimentation

Most of the sediment flows into the reservoir during the flood or the ice flood season, while the reservoir sedimentation flushing operation is generally performed during the ice flood season (March) and the sedimentation flushing season (August to September) each year. The distribution characteristics of the reservoir sedimentation are closely correlated with factors such as the inflow and sediment conditions into the reservoir, operation mode of the reservoir, and topographical conditions in the reservoir area. The operation mode adopted during the sedimentation flushing period

significantly affects the volume of sedimentation flushing, which in turn influences the distribution characteristics of reservoir sedimentation.

4.1 Impact of the reservoir water level

A “store clear water and discharge muddy water” operation mode was adopted in Wanjiashai Reservoir, where, according to the designed operation mode, the water level was lowered and the sedimentation flushing was performed during the flood season. Figure 4 showed the changes in the sediment deposition ratio and the average and lowest daily water levels of the Wanjiashai Reservoir during the flood season. This figure demonstrated that, as the water level was lowered during the flood season, the volume reservoir sedimentation flushing increased and the volume of deposition decreased slowly, thereby reducing the sediment deposition ratio accordingly. From the start of operation to 2010, the primary operation mode of Wanjiashai Reservoir during the flood season was to retain sediment. During this period, the operation water level was relatively higher, with the average value between 960 and

970 m, and the sediment deposition ratios were all above 97%; the reservoir basically did not perform any sedimentation flushing operation. From 2011 to 2017 (except 2016), sedimentation flushing operation was performed during flood season, and the average water level was kept between 960 and 966 m. Compared to their values during the period of 2002 to 2010 (Table 4), the highest and the lowest operation water levels were lowered by 1.39 m and 15.06 m, respectively, during the sedimentation flushing season, and the sediment deposition ratio was reduced to as low as 49% (during the flood season of 2015), with the reservoir switching to a scouring state.

Regarding non-flood seasons during 2000 to 2005, the average water level varied between 960m and 972 m. During 2006 and 2010, owing to the implementation of the “Test to utilize and optimize the scouring process of the spring flood to reduce the elevation of Tongguan”^[17], the reservoir operation mode was adjusted. Therefore, the

water level was lowered during the spring flood season, and the water level varied between 969m and 972m during non-flood season. During 2011 to 2017, the average water level during the non-flood seasons was slightly elevated, varying between 971 and 974 m. From Figure 5, which diagramed the changes in sedimentation and water level of the Wanjiashai Reservoir during the non-flood season between October 1999 and October 2017, it can be seen that the sediment deposition ratio did not change significantly with the average water level during the non-flood season, but instead was closely correlated with the lowest daily average water level in the three months of sedimentation flushing during the non-flood season. Between 2002 and 2005, the lowest daily average water level varied between 955 and 959 m, and the sediment deposition ratios were all above 80%; from 2006 to 2010, the lowest daily average water levels were all about 952 m, and the sediment delivery rate varied between -23% and 77%.

Table 4 Changes in the water level of the Wanjiashai Reservoir during different periods and seasons.

Year	Period	Maximum daily water level -m-	Minimum daily water level -m-
2002 to 2005	Non-flood	977.9	956.33
	flood	976.73	956.4
	sedimentation flushing	973.25	960.08
2006 to 2010	Non-flood	978.74	952.03
	flood	976.44	954.94
	sedimentation flushing	972.63	955.07
2011 to 2017	Non-flood	978.28	954.89
	flood	977.61	939.88
	sedimentation flushing	975.05	939.88

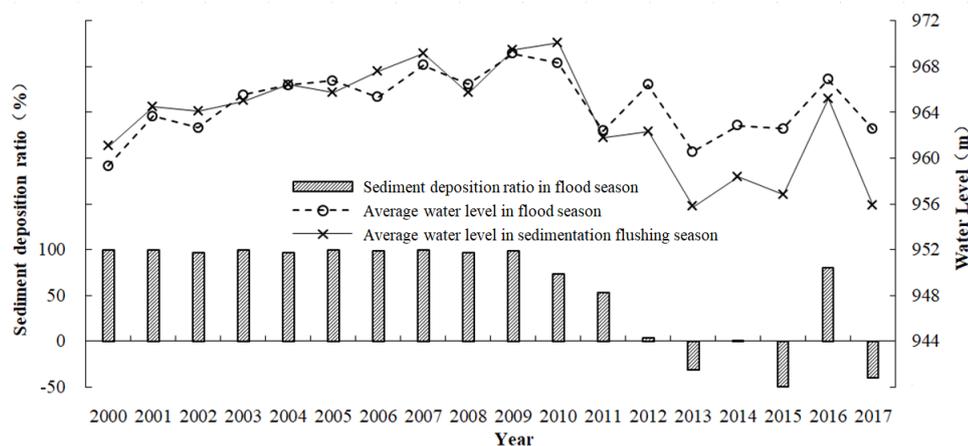


Fig. 4 Sediment deposition ratio and water level during the flood season between October 1999 and October 2017.

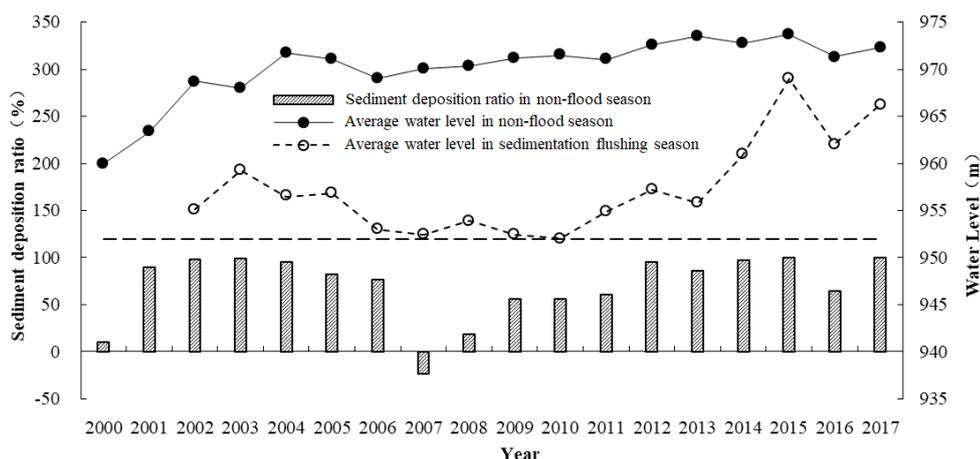


Fig. 5 Sediment deposition ratio and water level during the non-flood season between October 1999 and October 2017.

Figure 6 showed the relationship between the daily average sediment deposition ratio and the daily average operation water level under reservoir sedimentation flushing operation in the flood season between 2003 and 2017. From the figure, it was noted that, when the water level was above the flood control level of 966 m, sediment depositing occurred in the reservoir area; when the water level was between 952 and 957 m, both sediment scouring and depositing occurred, with scouring slightly dominating; and when the water level was below 952 m, the reservoir sediment deposition ratio

was less than 0, indicating the reservoir was scoured. It was also seen from the figure that, the lower the reservoir sediment deposition ratio, the more effective the reservoir sedimentation flushing. This is because during sedimentation flushing period, the lower the water level, the shorter the backwater distance in the reservoir area. Consequently, the sediment scouring amount of original river channel increases, and sedimentation transport distance in reservoir area reduces, thereby increasing the sediment delivery rate.

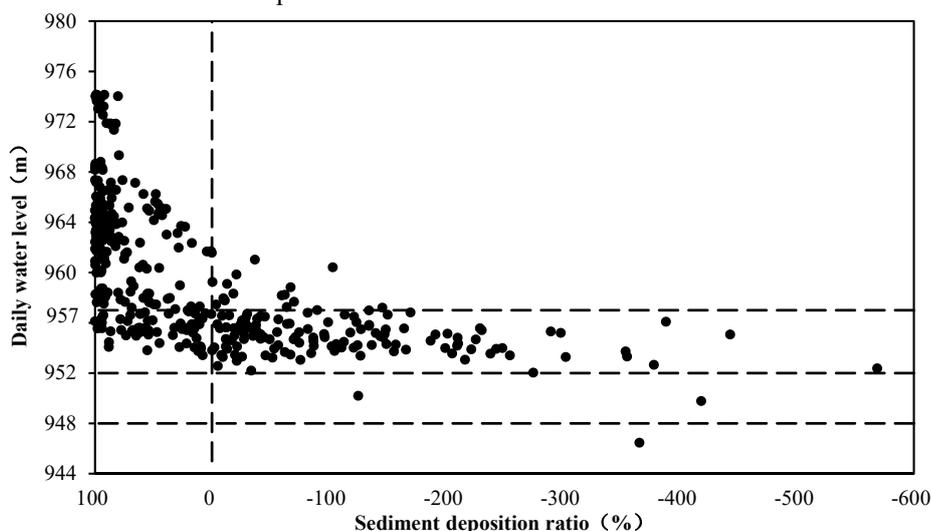


Fig. 6 Relationship between the sediment deposition ratio and the daily average water level of the Wanjiashai Reservoir during the flood season.

4.2 Influence of the water and sediment conditions

Since the operation of the Wanjiashai Reservoir, the Yellow River has experienced a series of low water events. Therefore, the reservoir inflow has mostly been on the low side, with relatively less runoff and sediment [19]. Based on the hydrological statistics collected at Toudaoguai station, from 2000 to 2017, the station recorded an average annual runoff of 15.95 billion m³ and an average annual discharge of 40 million tons, with average annual sedimentation concentration of 2.53

kg/m³. Between 2000 to 2005 and 2015 to 2017, runoff was relatively lower, while between 2006 and 2014, the water level was relatively higher (seeing Table 5). Figure 7 showed the relationship between the deposition volume and the sediment volume into Wanjiashai Reservoir, it could be noted that these two variables are positively correlated. Compared to those during 2000 to 2005, the average values of water and sediment into the reservoir both increased during the period of 2006 to 2010, resulting in an increase of 13 million tons in the average deposition volume during the flood season when the operation mode remained the same.

Table 5 Water and sediment statistics collected from the hydrological station at Toudaoguai in different periods and seasons.

Year	Runoff -billion m ³ -			Sediment -million t-			Sediment concentration -kg/m ³ -		
	Year	Flood	Non-flood	Year	Flood	Non-flood	Year	Flood	Non-flood
2000-2005	12.76	4.42	8.34	27	14	13	2.13	3.15	1.59
2006-2010	17.83	6.85	10.98	58	28	30	3.26	4.15	2.71
2011-2014	20.80	10.17	10.63	54	34	20	2.58	3.31	1.87
2015-2017	12.77	4.71	8.05	18	11	7	1.43	2.31	0.91
2000-2017	15.96	6.42	9.54	40	22	18	2.52	3.40	1.92

During the preliminary operation period of the Wanjiashai Reservoir, the primary operation mode adopted was to store water and retain sediment. As such, the operation water level was high and the sediment deposition speed was rapid. For example, in 2006, the sediment volume entering into the reservoir was 67.4 million tons, resulting in a deposition volume of 59.3 million tons, which was the largest deposition volume since the Wanjiashai Reservoir was put in operation; the sediment deposition ratio was 88%. The volumes of

water and sediment entering into the reservoir were the largest in 2012, with 28.5 billion m³ and 76.0 million tons respectively, while the deposition volume was 26.4 million tons and the sediment deposition ratio was only 35%. Compared to the value in 2006, sediment volume into the reservoir was relatively more in 2012, but the operation water level was low during the sedimentation flushing period, and therefore the deposition volume was relatively less.

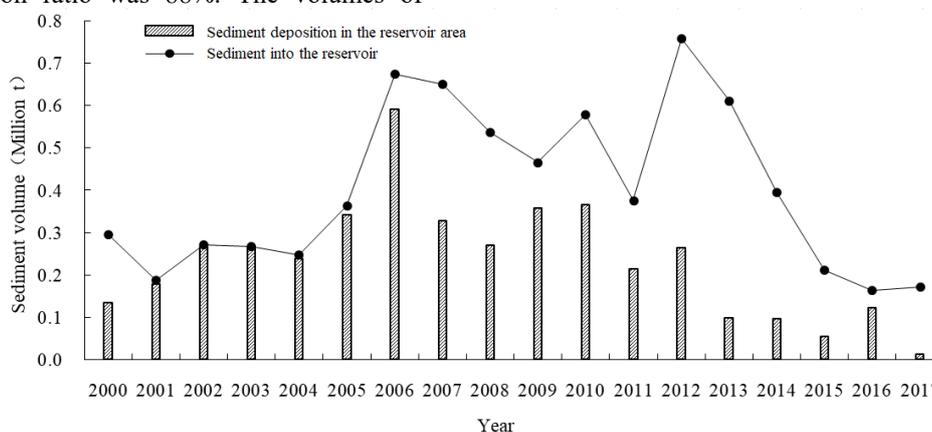


Fig. 7 Relationship between the deposition volume and the sediment volume into Wanjiashai Reservoir.

5 Conclusion

(1) The temporal distribution characteristics of the sedimentation of Wanjiashai Reservoir were as follows: during 2000 to 2017, the reservoir area was dominated by continuous sediment deposition, among which the annual deposition volume was reduced between 2011 and 2017. From 2000 to 2017, the deposition volumes during the flood season and non-flood season occupied 51% and 49% of total, respectively. In terms of the sediment deposition ratio, between 2000 and 2010, the sediment deposition ratio was generally above 95% during the flood season. From 2011 to 2017, the sediment deposition ratio was significantly reduced, dropping to 6.9% in 2017.

(2) The spatial distribution characteristics of the sedimentation of Wanjiashai Reservoir were as follows: in terms of the sedimentation distribution between the main stream and the tributaries, the sedimentation was mainly deposited at the main stream; the total deposition volume at the main stream was 386.1 million m³ between 2000 and 2017. Sediment deposition occurred primarily downstream of the WD54 section to dam site, with the most of the deposition position being located downstream of the WD23 section. At the tail of the

reservoir area from WD54 to WD65 (72 km from the dam), sediment scour and deposition volume did not change substantially. From 2011 to 2017 (except 2016), sedimentation flushing operation was performed at Wanjiashai Reservoir, and from 2011 to 2013, the sediment deposition feature in reservoir area was overall upstream scouring and downstream deposition, indicating that the sedimentation feature has been adjusted.

(3) The distribution characteristics of the sedimentation in the reservoir area are closely correlated with factors such as the water and sediment conditions and the operation mode of the reservoir. As the dam water level was lowered during the flood season, the sedimentation flushing volume increased, and the sediment deposition ratio decreased correspondingly. When the operation water level was above 966 m, which is the flood control level of the reservoir, sedimentation was deposited in the reservoir area. Alternatively, when the operation water level was kept between 952 m and 957 m, both scour and deposition were present in the reservoir area, with slightly scour. When the operation water level was below 952 m, the sediment deposition ratio was less than 0, indicating that the reservoir area

had been scoured.

(4) Based on measured data, the sedimentation distribution characteristics of the Wanjiashai Reservoir were analyzed from various aspects. In terms of the temporal distribution, between 2006 and 2010, the sediment deposition ratio during the non-flood season significantly decreased, and the average annual sediment deposition ratio was reduced to 38%, indicating that sedimentation flushing operation mode was effective during the non-flood season, especially in the ice flood period. It is recommended to carry out some research to adjust operation mode of Wanjiashai Reservoir during the sedimentation flushing season and the ice flood season as soon as possible, and research the operation mode with lowering water-level to flush sedimentation in a timely manner to improve the sediment deposition conditions in the reservoir area.

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