Observation of Sediments Transport in Three Georges Reservoir during Middle and Small Flood Operation

Zhou Yinjun[1*], Qian Sheng[2] and Wang Xi[1]

[1]Changjiang River Scientific Research Institute, Wuhan, China

[2]Hunan Huaihua Hydro Electric Design Institute , Huaihua, China

Email: zhouyinjun1114@126.com

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Abstract. Based on the observed data, we used the method of analogy years to analysis the effect of middle and small flood control to sediments transport in the TGR. The analogy year is 2007, 2006 and 2008, whose water and sediments condition was similar with the year 2010 to 2012. Compared with the flood season in 2007, 2006 and 2008 successively, the deposition increased 2042 $\times 10^4$t in the flood season of 2010, which was the 11.4% of deposition in 2010, increased 210 $\times 10^4$t in the flood season of 2011, which was the 2.3% of deposition in 2011, increased -350 $\times 10^4$t in the flood season of 2012, which was the 2% of deposition in 2012. The result shows that, in the years with small sediments runoff, the middle and small flood operation can't increase obvious deposition, but in that years with more sediments runoff, the middle and small flood operation need further optimization.

Introduction

Three Georges Reservoir(TGR) is a key project with function of flood control, hydropower, navigation, water supply, and the first function is flood control, it is the key project of Yangtze River flood control system. TGR's normal pool level is 175m, total capacity of reservoir is $393 \times 10^8 m^3$, limiting level during flood season is 145m, flood control storage is $221.5 \times 10^8 m^3$, drawdown level during dry season is 155m, effective storage is $165 \times 10^8 m^3$.After the 2008 flood season, TGR carried on testing impoundment, and the water level before the dam(LBD) firstly arrived 175m in October 2010, it signed that TGR possess ability to play any benefits which was given by designs.

There were two plans of flood control operation in the preliminary design: one operation plan aimed at control Shashi flood level in Jingjiang river, the other operation plan aimed at control Chenglingji flood level downstream Jingjiang river, where, the first plan is the recommended solution. In the plan, when the flood in Zhicheng was less than $56700 m^3/s$, TGR should carried on flood regulation to ensure that the water level in Shashi don't outstrip 44.5m, if the flood was more than $56700 m^3/s$, TGR should carried on flood regulation to ensure that the discharge in Zhicheng don't outstrip $80000 m^3/s$. when the LBD arrived 175m, TGR's operation should ensure the dam is safe.

So, in flood season, only encounter the big flood, the reservoir can impound flood. The manager made the operation plan-clear water impounding and muddy flow releasing, for the adverse effect of sediments deposition to reservoir capacity, This way not only decreased sediments deposition in flood season, but also ensured the enough capacity when the big flood was coming.

Recently, because the decreasing of sediments runoff and improvement on expectation of TGR's flood control benefit, managers wanted to adjust initial operation plan, they carried on the middle and small flood(MSF) control. on the one hand, the new flood control can ease the flood force in the downstream, on the other hand, it can add water head in flood season, enlarge power and energy output of hydropower station, the flood changes into resource. But the effect to the reservoir deposition is valued to pay more attention.

From the firstly middle and small flood retarding in flood season of 2009, TGR continued to carry on middle and small flood operation four times. For 2009 and 2013 to be example, we used the observed data analogy and numerical model to analysis the effect to the reservoir deposition.

Method and Plan

We used the observed data about inlet & outlet water and sediments, level front dam, to analysis the sediment flux transportation and MSFC's effect to the reservoir deposition.

The observed data of reservoir operation from 2003 to 2013 was shown in Table 1, from the schedule, we can choice similar year as water and sediment process of 2009 and 2013.

Table 1 Input & output water and sediments condition of TGP

Year	Inlet		Outlet		Deposition	SRR	Flood season LBD
	Water	Sediment	Water	Sediment			
2003.6-12	3254	20810	3386	8400	12410	40.4%	135.23
2004	3898	16600	4126	6400	10200	38.4%	136.58
2005	4297	25400	4590	10300	15100	40.6%	136.43
2006	2790	10210	2842	891	9319	8.7%	138.67
2007	3649	22040	3987	5090	16950	23.1%	146.44
2008	3877	21780	4182	3220	18560	14.8%	148.06
2009	3464	18300	3817	3600	14700	19.7%	154.46
2010	3722	22880	4034	3280	19600	14.3%	156.37
2011	3015	10163	3391	692	9471	6.8%	154.52
2012	4166	21900	4642	4530	17370	20.68%	158.17
2013	3345	12700	3694	3280	35000	25.83%	-
Total	39477	202783	42691	49683	178680	24.50%	

The comparison of sediments runoff are used to choice similar year, the results can be shown in Table2. So from Table2, we choice couple 2, couple 3 and couple 4 to analogy analysis, the deposition changes can be calculated by the Formula (1):

Deposition changes= (inlet sediments in flood season × SRR of similar year) − actual outlet sediments in flood season (1)

Data Analogy

Between May and October, 2010, the input and output sediment of TGR were 2.239×10^8t and 0.326×10^8t, the flood more than 50000 m^3/s appeared 3 times, maximum flood was 70000 m^3/s. TGR retarded flood 7 times, total retarded $264.3\times10^8m^3$ flood, and the reservoir deposition was 1.91×10^8t, Sediment releasing ratio(SRR, output sediment/input sediment) was 14.5%, which was less than 29.3% during the same period from 2003 to 2013. The sediment deposition was 0.947×10^8t, SRR is 16.8%, which was less than 26.1% during the same period from 2003 to 2013. The process of water level before dam was shown in Fig.1.

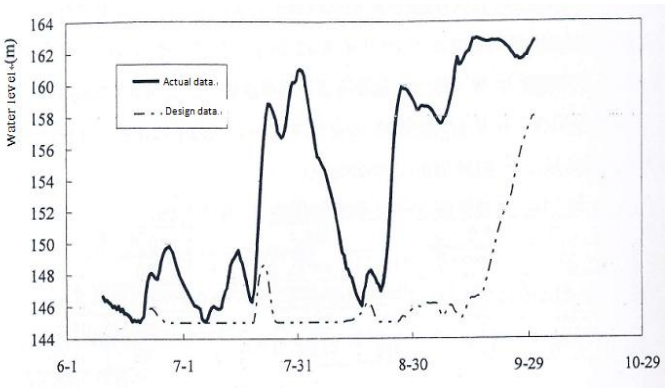

Figure 1 The actual and design water level before dam in 2010 flood season

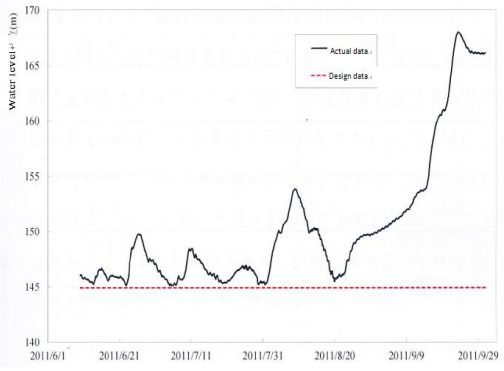

Figure 2 The actual and design water level before dam in 2011 flood season

Between May and October, 2011, the input and output sediment of TGR were 0.971×10^8t and 0.0593×10^8t. TGR retarded middle and small flood 4 times, total retarded 247.2×10^8m^3 flood, the maximum flood level before dam was 167.98m, average level was 148.0m. SRR was 6.1%, which was less than 17.2% during the same period from 2008 to 2009, and less than 14.5% of 2010. The process of water level before dam was shown in Fig.2.

The water and sediment condition of 2010 was similar as 2007, the average flood season LBD of 2007 was 146.44m, which was nearby 145m of design. SRR of each year was shown in Fig.3. If the SRR of 2007 flood season was used to estimate the 2010 sediment deposition, for retarding middle and small flood, the extra deposition was 2042×10^4t, and 11.4% of total deposition in 2010 flood season, the SRR was 15.3%.

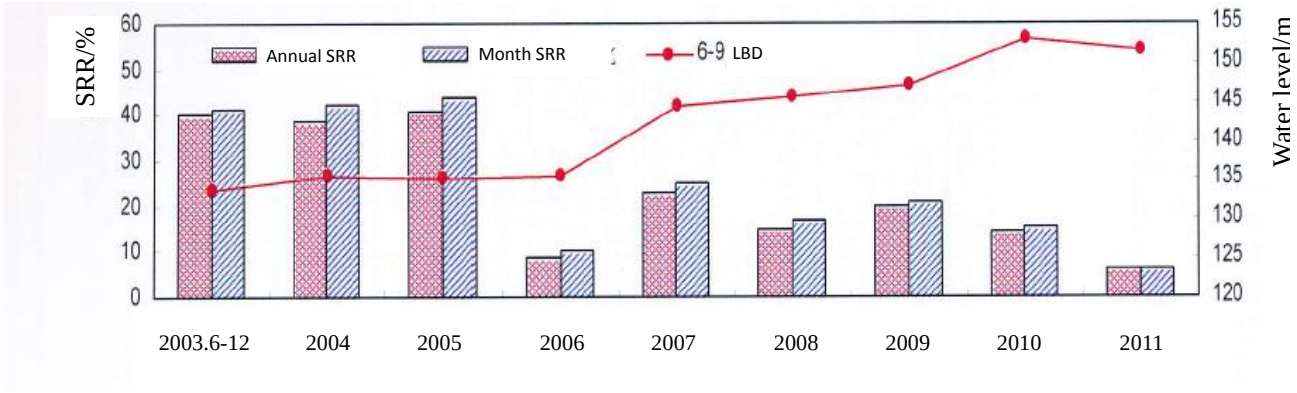

Figure 3 Sediment releasing ratio(SRR) and water level before the dam from 2003.6 to 2011.12

The water and sediment condition of 2011 was similar as 2006, the average flood season LBD of 2006 was 138.67m, which was lower than 145m of design. If the SRR（9.2%） of 2006 flood season was used to estimate the 2011 sediment deposition, for retarding middle and small flood, the extra deposition was 210×10^4t, and 2.3% of total deposition in 2010 flood season, the SRR was 7.0%.

The water and sediment condition of 2012 was similar as 2008, the average flood season LBD of 2008 was 148.06m, the average flood season LBD of 2012 was 158.17m. If the SRR（19%） of 2008 flood season was used to estimate the 2012 sediment deposition, for retarding middle and small flood, the extra deposition was - 350×10^4 t, and 2% of total deposition in 2012 flood season, the SRR was 20.6%.

Table 2 The comparison of sediments runoff between actual and similar year

Couple	Actual Year	Similar year	Gap(%)
1	2009	2003	-12.1
2	2010	2007	+3.8
3	2011	2006	-0.5
4	2012	2008	+0.5
5	2013	2005	-23.5

Results

In conclusion, because the flood season LBD of 2010 was higher than design data, so that the reservoir deposit more 20,420,000t, which was 11.4% of total deposition in 2010 flood season.

By comparison between SRR of 2006 and 2011, because the flood season LBD of 2011 was higher than 145m, so that the reservoir deposit more 2,100,000t, which was 2.3% of total deposition in 2011 flood season.

Although the LBD of 2012 is higher than similar year , the sediment deposition decrease 3.5 million t with the SRR of similar year. Which was 2% of total deposition in 2012 flood season.

The result shows MSFC may increase deposition in flood season, but the operation plan be continued to developed, especial the transportation test with the nonsynchronous flood and sediment peak , which can increase the SRR, even decrease the deposition.

Conclusions

From the year 2003 to 2013, the total deposition of TGR is 17.87×10^8t , the total SRR is 24.9%. More than 90% of deposition occurs in permanent backwater area , especial in the downstream part.

Finally, in 2010 and 2011, the middle and small flood control accused the sediments deposition increased, but the inlet sediment is less than design data, the extra deposition can't effect the long range impoundment of TGR, in 2012 , the MSFC don't accused the extra deposition, maybe it correlated with the developing operation plan .

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