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News & Highlights

Reflections on the Three Gorges Project since Its Operation

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1. Introduction

The initial design of the Three Gorges Project (TGP) planned for three phases in the impoundment of its reservoir: the power generation period, with the water retained by a cofferdam; a preliminary operation period; and then a normal operation period. In 2003, the Three Gorges Reservoir was impounded to elevation (El.) 135 m, and power generation began with the water being retained by a cofferdam. In 2007, the reservoir was impounded to El. 156 m, and preliminary operations began. By 2009, as the main hydraulic structures were completed, the reservoir was fit to be impounded to its normal level of El. 175 m. However, it was still kept at the pool level during the preliminary period. Based on considerations of the resettlement progress, observed results of sedimentation at the reservoir tail area, the influence of sedimentation on Chongqing Port, and so forth, the duration of the preliminary operation period was determined at six years. Subsequently, in 2013, the Three Gorges Reservoir was impounded to its design pool level of El. 175 m; hence, the normal operation period began.

Preparations for the construction of the TGP began in 1993, the work commenced in December 1994, and the main river was closed on November 6, 1997. In 1998, construction of the dam and powerhouse on the left bank began. In October 2002, water passed through the diversion bottom outlets at the flood-sluicing dam, and on November 6 of the same year, the open diversion channel was completed; the flood-sluicing dam, the powerhouse, and the non-overflow dam section on the left bank and the head bay at the ship lift were completed and began retaining water. In June 2003, the reservoir was impounded to El. 135 m; in July, the first batch of generating units in the left powerhouse began generating power and the dual-line five-step continuous shiplock began operation. In 2004, construction of the dam and powerhouse on the right bank began, and by 2005, all 14 generating units in the left powerhouse commenced operation. In June 2006, the dam section on the right bank was concreted up to El. 185 m and the upstream roller-compacted concrete (RCC) cofferdam was demolished by blasting; thus, the whole dam began retaining water. In October, the reservoir was impounded to El. 156 m, marking the start of the preliminary operation period one year ahead of schedule. In 2007, the seven generating units in the powerhouse on the right bank began operation. In August 2008, the dam, powerhouse, and dual-line five-step continuous shiplock were all completed; the resettlement of counties and towns was completed; and programs on resettlement, the reservoir area clear-up, geological hazard control, water pollution control, ecological environmental protection, and the preservation of cultural relics were all finished and approved by relevant authorities. At this point, the reservoir was ready to reach its normal pool level of El. 175 m. Approved by the TGP Construction Commission of the State Council, the reservoir began to tentatively impound to El. 175 m at the end of the 2008 flood season, marking the shift from its operation at an El. 156 m pool level to its trial operation at El. 175 m.

2. Changes in hydrological regime in the upper Yangtze River and the optimized operation of the Three Gorges Reservoir

2.1. Flood characteristics at the Three Gorges Project (TGP)'s damsite

Flooding at the TGP's damsite consists of floods from the Jinsha River (i.e., the upper trunkstream of the Yangtze River) and various tributaries. Major floods upstream of the damsite are caused by extensive and heavy rainfall in the upper regions of the Yangtze River, mainly from July to September. Since the Minjiang, Tuojiang, and Jialingjiang Rivers (as shown in Fig. 1) at the northern banks of the Yangtze River flow in a north-to-south direction through the rainstorm-prone area in western Sichuan Province and the Daba Mountain, the river flow and the rainfall movement synchronize. The tributary floods meet with the floods from the upper trunkstream and the interval flood from the trunkstream, thereby forming a major flood in the upper trunkstream. A flood at the damsite is considered in light of the maximum peak discharge (71 100 $m^3 \cdot s^{-1}$) observed at the Yichang Hydrometrical Station since 1877, with an empirical maximum peak discharge of 105 000 $m^3 \cdot s^{-1}$. The dam is designed according to a 1000 year frequency flood discharge of 98 800 $m^3 \cdot s^{-1}$ with its corresponding design flood level of El. 175 m, and checked against a flood discharge of 124 300 $m^3 \cdot s^{-1}$ (i.e., a 10000 year frequency flood discharge of 113 000 $m^3 \cdot s^{-1}$ plus its 10% flood discharge), with its corresponding checked flood level of El. 180.4 m.

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2.2. Changes in hydrological regime in the upper Yangtze River

Hydrometrical data observed at the Yichang Hydrometrical Station are used as preliminary design values for the TGP, with an annual average runoff of 4.51×10^{11} m^3 and an annual average sediment load of 5.21×10^8 t [1]. Since the 1990s, runoff reduction from the upper Yangtze River has been limited and affected by rainfall change; while due to the efforts of sediment retention by hydro projects, sediment reduction by soil and water conservation, and river sand-mining, incoming sediment was prominently decreased (as shown in Table 1).

The reduction of incoming sediment into the reservoir is beneficial to its long-term operation. From 2003 to 2015, the annual average runoff at the damsite was 4.003×10^{11} m^3, which reduced by 5.07×10^{10} m^3 (11.24%) when compared to its preliminary design value. The seasonal change in upstream runoff is similar to that of rainfall, and is unevenly distributed within a year, i.e., runoff during the flood season from June to October accounts for 70%–75% of the annual total. Over the past 20 years, the runoff during flood season, and in October to November, has been lower than the preliminary design value, and it increased from December to May of the following year [2].

2.3. Preliminary operation mode for the TGP

The preliminary operation mode designed for the TGP is as follows. During every flood season from mid-June to late September, the reservoir is operated at the flood control level of El. 145 m. When the level rises to El. 145 m, the flow discharged from the reservoir is 55 000 m^3·s^{-1}, so as to ensure that the discharge at the Zhicheng Hydrometrical Station of the Jingjiang River reach does not exceed 56 700 m^3·s^{-1}. In the case of a flood with a discharge of less than 55 000 m^3·s^{-1}, water is completely discharged down to El. 145 m. If a flood has a discharge of more than 55 000 m^3·s^{-1}, flood control operation must be conducted for the downstream reach; that is, the reservoir impounds this flood and controls the discharged flow. As the impounded flood will cause the water level to rise, once the flood process recedes, the water level must be lowered to El. 145 m again for the purpose of controlling subsequent floods. The operation mode of "storing clear water and discharging muddy water" is adopted for the Three Gorges Reservoir; that is, the reservoir impounds water after the flood season (early October) so as to scour sediment in the Chongqing reach at the tail area of the Three Gorges Reservoir. Considering the need for navigation in the downstream reach, the minimum flow discharged from the reservoir during impoundment is required to be no less than 53 000–64 600 m^3·s^{-1}, corresponding to the firm output of the Three Gorges powerhouse; then the water level gradually rises up to El. 175 m. During the low-water season, it is generally operated at a higher water level in order to allow for power generation and navigation in the reservoir area. In order to meet flood control needs, the water level is required to be lowered down to El. 145 m at the end of early June before the flood season. During a flood season, the flood control operation is conducted in a flood control compensation mode for the Jingjiang River reach, increasing the flood control standard there from controlling a 10 year frequency flood to controlling a 100 year frequency flood. In

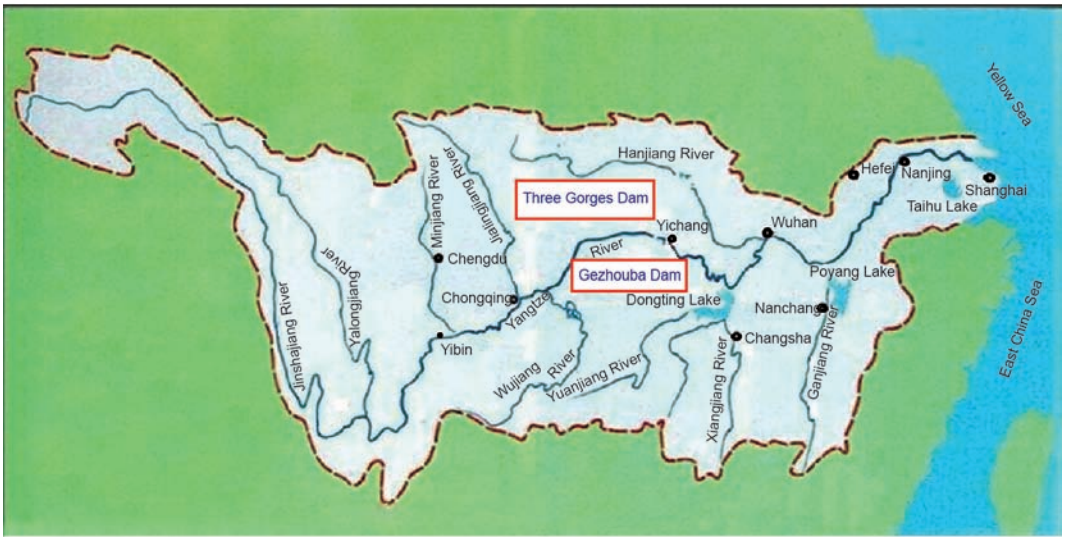

Fig. 1. A plan map for the comprehensive utilization of the Yangtze River Basin.

Table 1
Change in runoff and sediment load at the Three Gorges Project (TGP) damsite and flowing into the Three Gorges Reservoir.

Location	Annual average runoff (× 10^9 m^3)					Annual average sediment load (× 10^6 t)				
	Preliminary design value (1877–1990)	Before impoundment (1991–2002)		After impoundment (2003–2015)		Preliminary design value (1877–1990)	Before impoundment (1991–2002)		After impoundment (2003–2015)	
		Observed value	Compared to preliminary design value	Observed value	Compared to preliminary design value		Observed value	Compared to preliminary design value	Observed value	Compared to preliminary design value
TGP damsite	451.0	428.7	–4.94%	400.3	–11.24%	521	391	–25.0%	40.4	–92.2%
Site flowing into the Three Gorges Reservoir	401.5	387.1	–3.59%	369.0	–8.09%	491	357	–27.3%	164.5	–66.5%

Note: Cuntan and Wulong Hydrometrical Stations represent the site flowing into the Three Gorges Reservoir.