



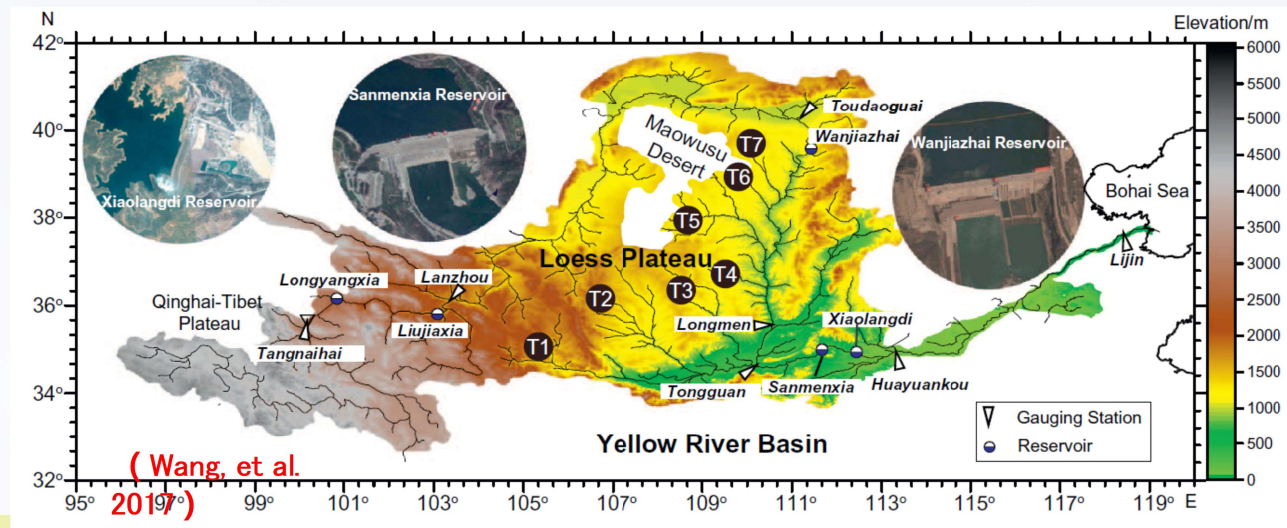
Practice and Effectiveness of Yellow River Water and Sediment Regulation in the New Situation

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1 What is Yellow River water and sediment regulation

- According to the inflow water and sediment characteristics of the Yellow River, Water and sediment regulation is to adjust the unfavorable water and sediment process to a relatively favorable one through the joint regulation and application of reservoir groups, so as to transport sediment into the sea, reduce the deposition of the river channel, and expand and maintain the bankfull discharge of the main channel.
- Since 2002 , lasting 22 years.
- **Three models:** single reservoir(Xiaolangdi Reservoir), spatial scale docking (mainstream and tributary reservoir groups joint regulation) , joint operation of reservoir groups and artificial disturbance of sediment



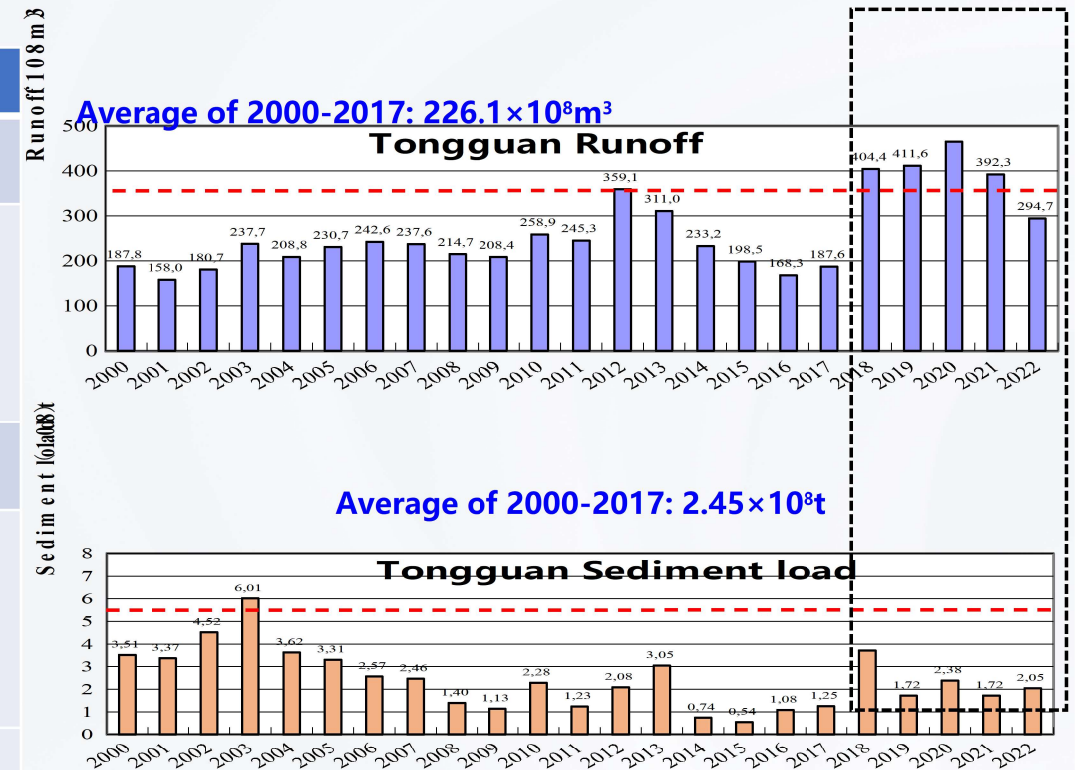
Scheduling diagram of artificial density flow

2 The new situation of the Yellow River

Water and sediment characteristic(2018–2022): More water, less sediment

The water and sediment situation of the Yellow River changed dramatically. In the past 5 years, the water volume in Tongguan is **39.17 billion cubic meters**, increased about **74 %** compared with the previous period, and the sediment load is **0.232 billion tons**, decreased about **6 %**.

Year	2018	2019	2020	2021	2022
Tongguan annual water volume (10⁸m³)	404.4	411.6	465.1	392.3	294.7
Compared with the average annual water volume from 2000 to 2017	79%	82%	106%	74%	30%
Tongguan annual sediment volume (10⁸t)	3.72	1.72	2.38	1.72	2.05
Compared with the average annual sand volume from 2000 to 2017	52%	-30%	-3%	-30%	-17%

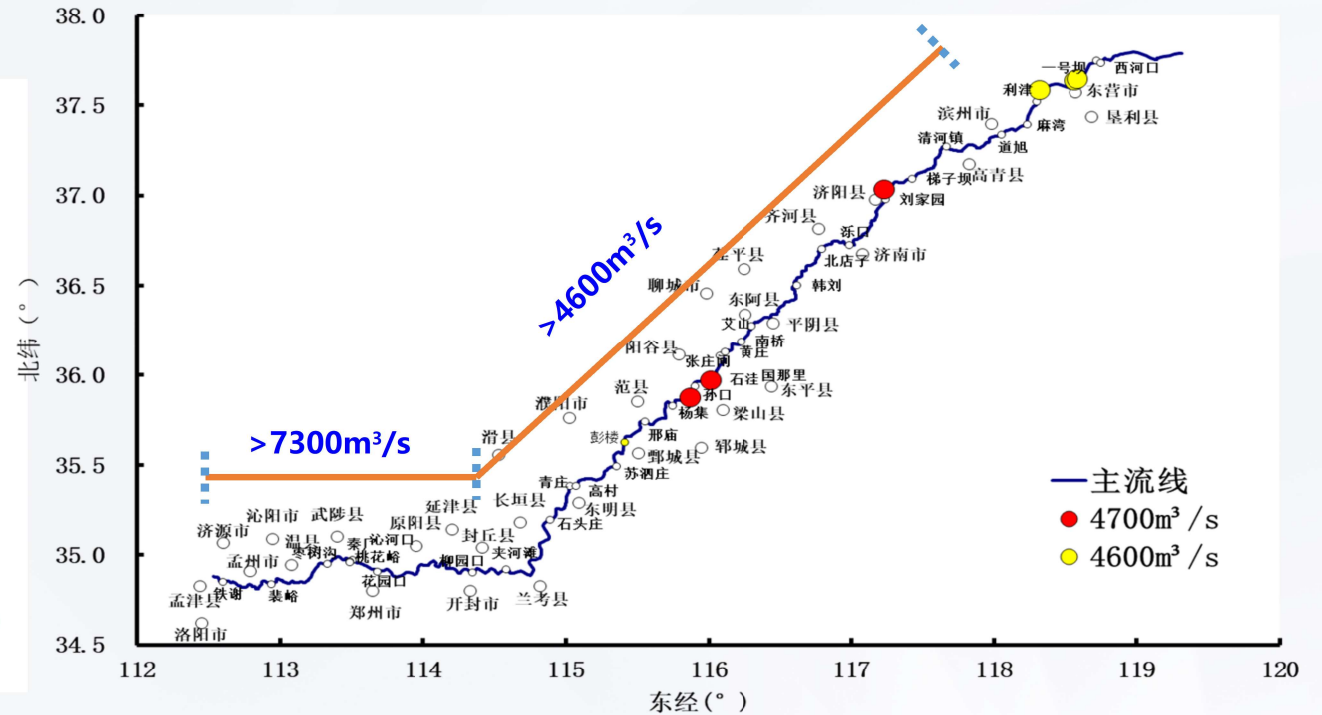
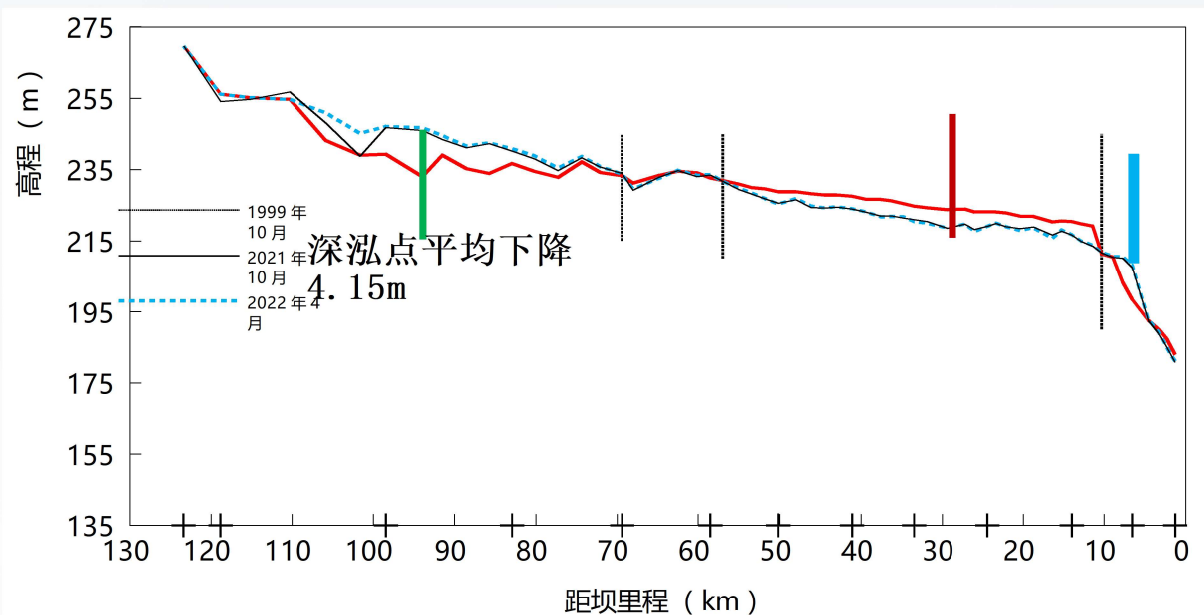


■ Xiaolangdi reservoir deposition condition

The Xiaolangdi Reservoir has accumulated 3.46 billion m³ of sediment
Distance between apex of silted delta and dam is reduced to 11.42km

■ Bankfull discharge of Lower Yellow River

The bankfull discharge of the downstream channel has increased from 1800 m³ / s at the initial stage of water and sediment regulation to 5000 m³/ s.



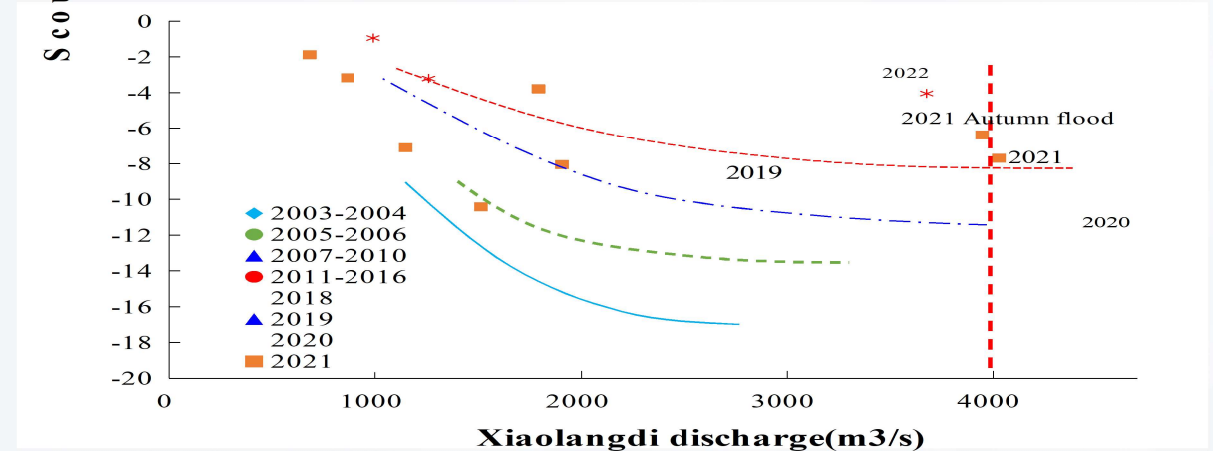
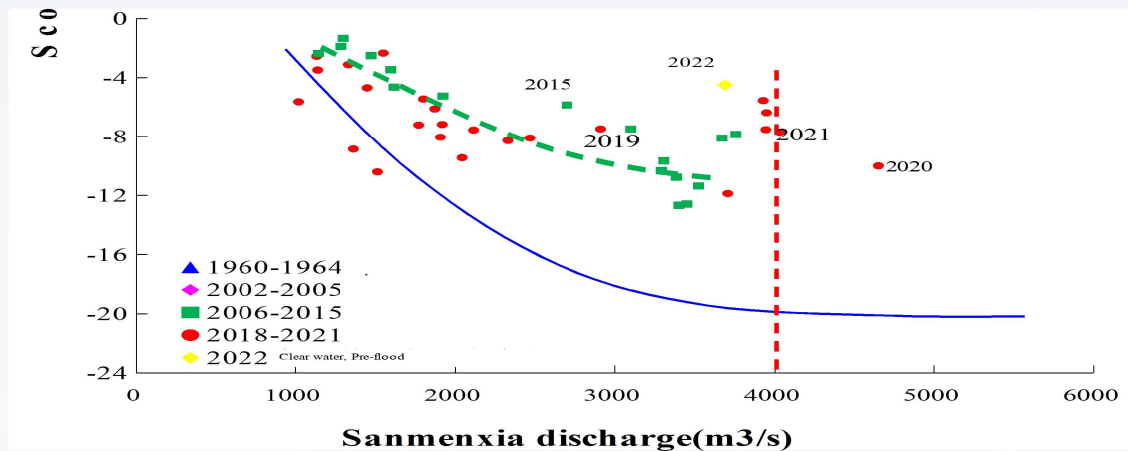
3 Key parameters optimization

- Based on the experiences of water and sediment regulation in past years, and the sediment transport rules of Xiaolangdi Reservoir and downstream channel, we optimized the key parameters of water and sediment regulation under the new situations, in order to further improve the sediment discharge efficiency of the reservoir and the sediment transport efficiency of the downstream channel.

Stage	Index	Consideration factors	Suggested indicators																								
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3 Key parameters optimization

(1) The clear water discharge of Xiaolangdi: 4000~4500m³/s

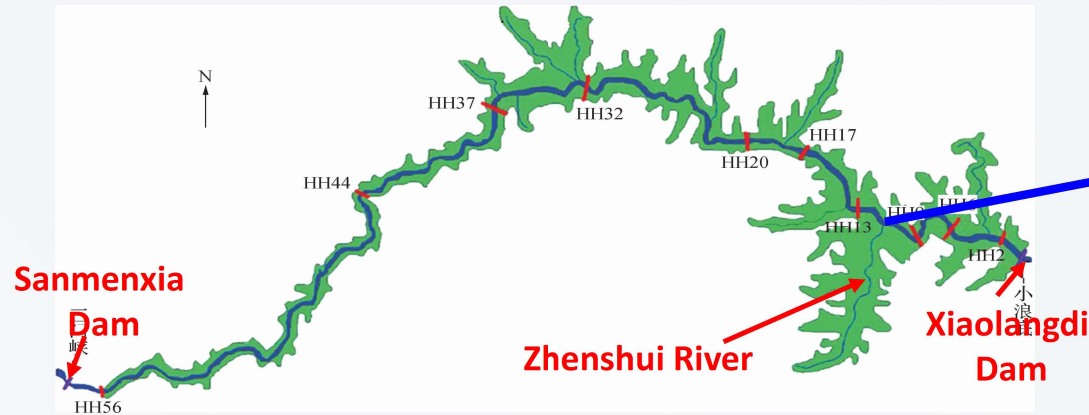


The relationship between downstream scouring efficiency and flood discharge of low sediment concentration (less than 5kg/m³) in Sanmenxia Reservoir and Xiaolangdi Reservoir

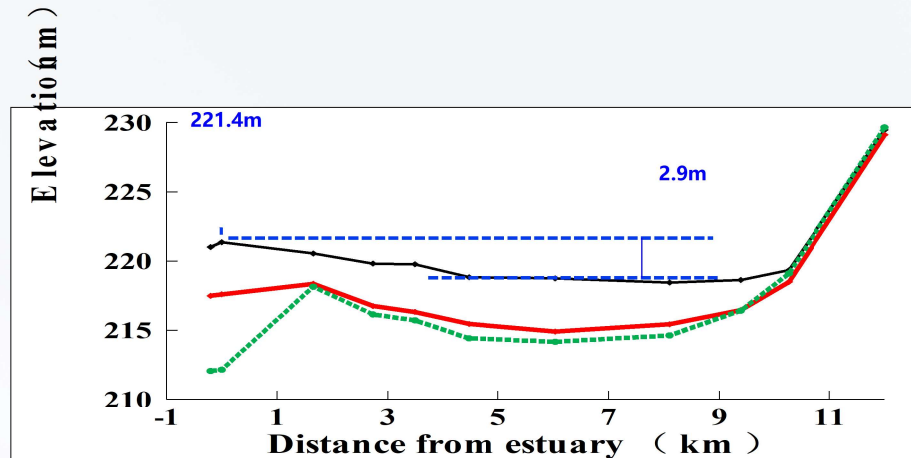
- With the increase of flow discharge, the scouring efficiency also increases, and the trend is obvious. **When the flow discharge reaches 4000~4500m³/s, the increasing trend is not obvious**
- Since 2003, with the development of erosion, the riverbed has been coarsening, and the erosion efficiency at the same flow rate has been decreasing

(2) The docking water level of 2023 : 215m

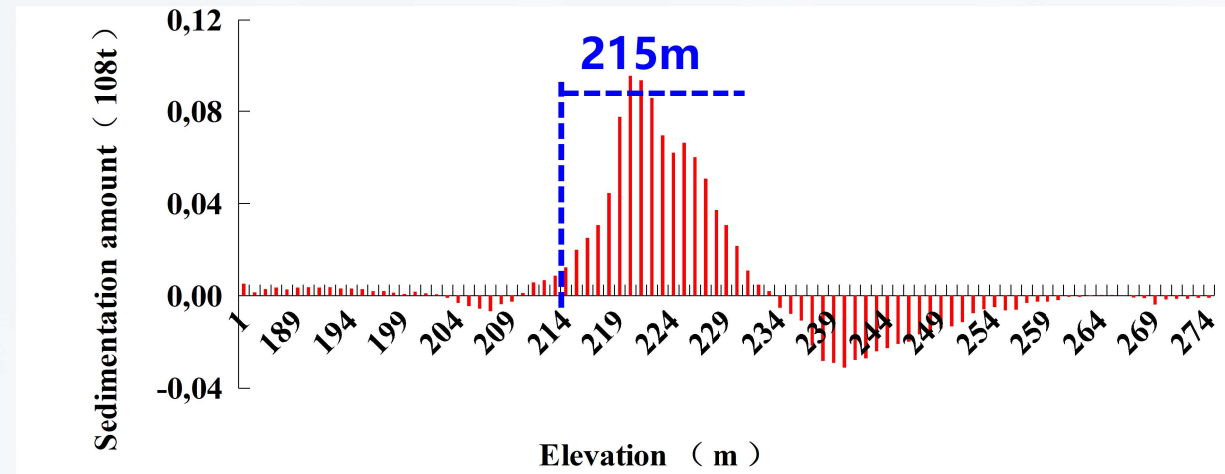
- The docking water level is very important for the occurrence of artificial density flow, optimize the deposition form of the main stream further more.
- It is also beneficial to the effective utilization of tributary reservoir storage(Zhenshui)



Channel formed by erosion of the Zhenshui River estuary

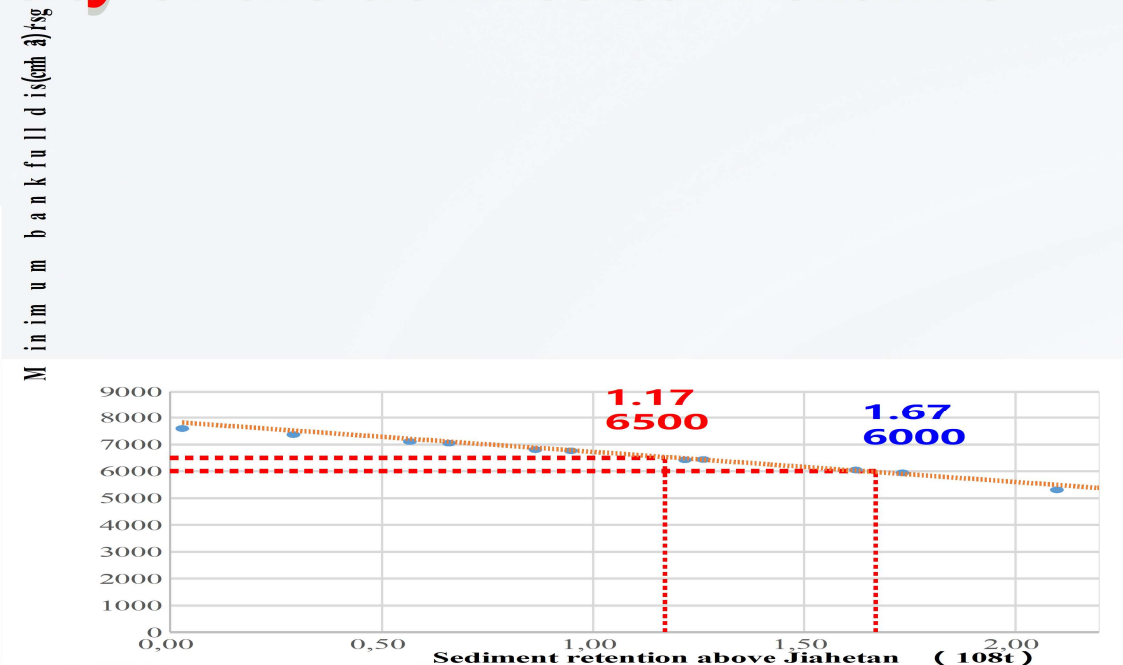
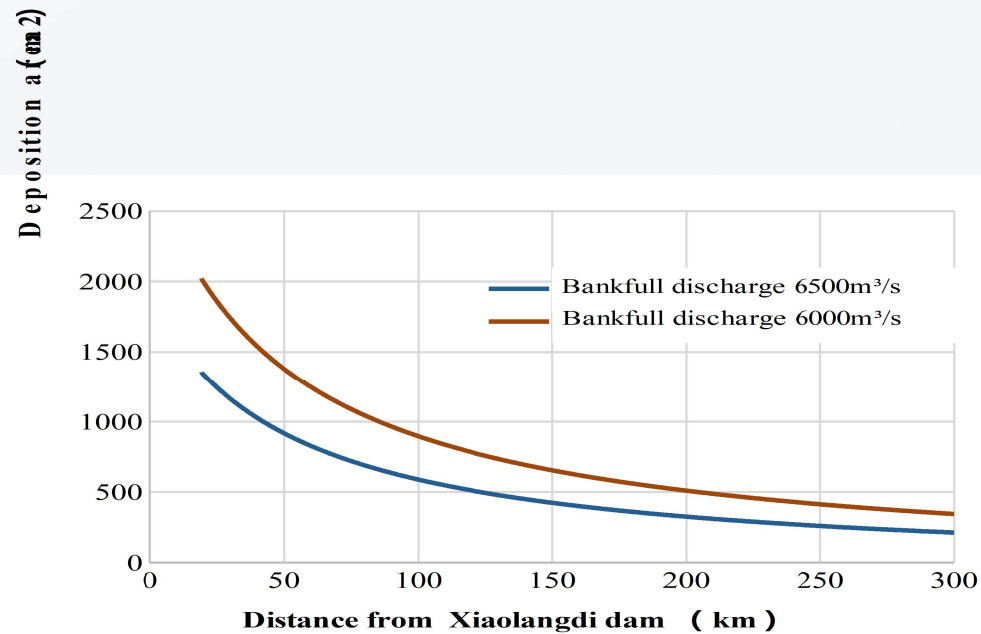


Zhenshui River longitudinal profile



The distribution of erosion and deposition in Xiaolangdi Reservoir 2022

(3) The sediment retention capacity of the downstream channel

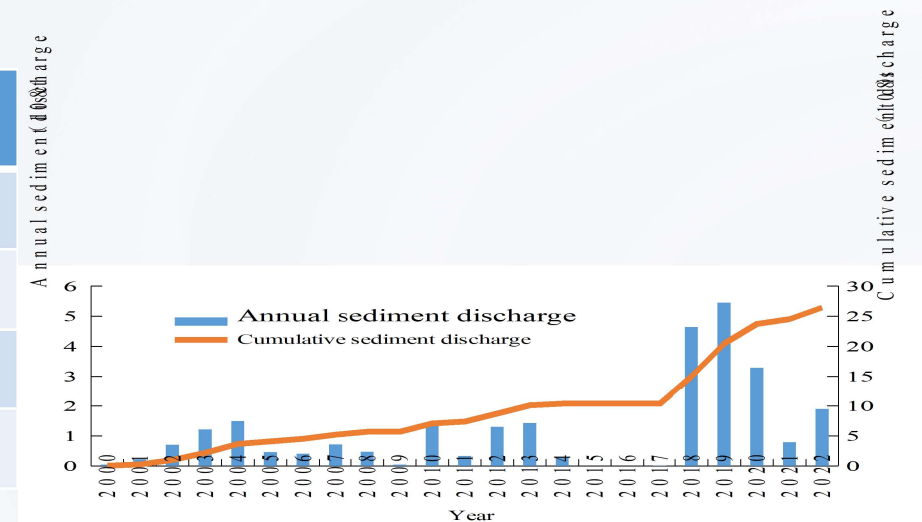


- At present, the minimum bankfull discharge above the Jiahetan is more than **7300 m³/s**. If the minimum bankfull discharge is not less than **6000~6500m³/s**, the sediment retention capacity of the river channel above the Jiahetan is calculated to be **117~167 million tons**
- In the stage of water and sediment regulation before flood season, 60% of the sediment is deposited in the upper reaches of Jiahetan. It is estimated that the sediment volume of Xiaolangdi Reservoir in the stage of water and sediment regulation should **not be more than 200 million tons**

Xiaolangdi Reservoir

- The Xiaolangdi reservoir has a total sediment discharge of 2.64 billion tons (2000-2022), and the remaining sediment retention capacity is about 4.1 billion m³, which provides a guarantee for flood control to the lower Yellow River
- Since 2018, the use of water and sediment regulation to carry out sediment discharge scheduling to slow down the deposition of Xiaolangdi Reservoir has achieved better results, basically keep the balance of sediment inflow and outflow

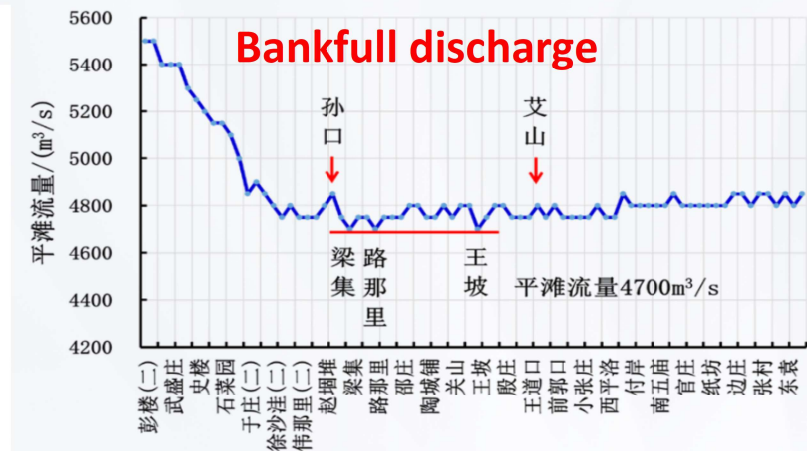
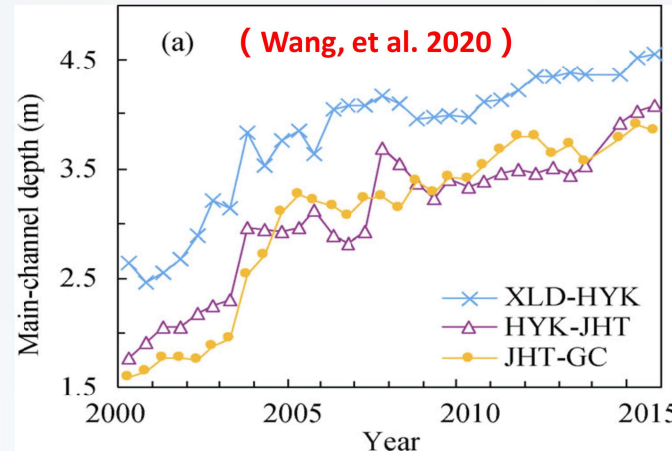
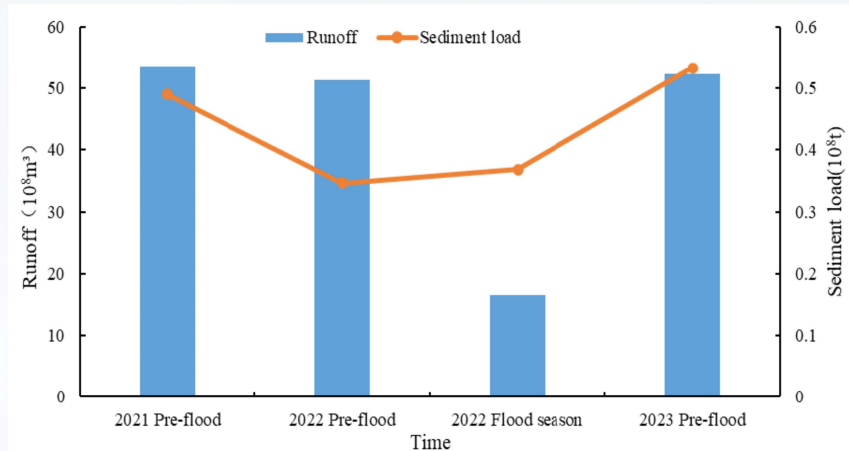
Time	Sediment inflow(10 ⁹ t)	Sediment outflow(10 ⁹ t)	deposition volume(10 ⁹ t)	Sediment delivery ratio(%)
2000-2006	2.73	0.45	2.29	16.5
2007-2017	2.31	0.59	1.72	25.4
2018-2022	1.64	1.60	0.03	98.0
2000-2022	6.69	2.64	4.04	39.5



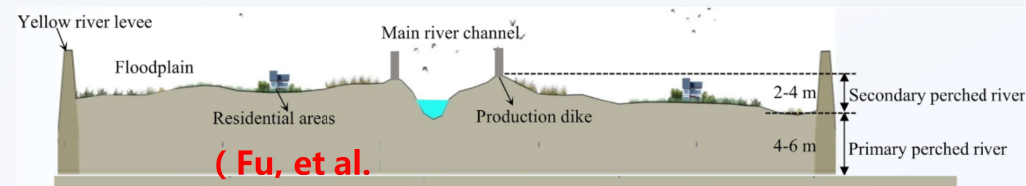
- In 2023, according water and sand regulation, the sediment inflow volume of Xiaolangdi reservoir is 0.0463 billion tons, the sediment outflow volume of the reservoir is 0.136 billion tons, and the scouring amount is 0.0898 billion tons, meanwhile, the accumulated sediment deposition in the lower reaches is 62.1 million tons

The downstream channel

- **Total sediment transport:** Since 2002, the water and sediment regulation has transported about **3.25 billion tons** sediment into the sea.
- **Sediment transport efficiency :** Especially since 2021, the 4 times of water and sediment regulation have used 17.37 billion cubic meters of water to transport 174 million tons of sediment into the sea. The average sediment transport efficiency is **10 kg/m³**, which is much higher than the previous sediment transport efficiency of **4 ~ 6 kg / m³**
- **Bankfull discharge:** the minimum flow capacity of the main channel is increased from 1800 m³ / s in 2002 to about **5000 m³/s** now.
- **River delta:** Since 2008, a total of **1.05 billion m³** of water has been replenished to the Yellow River estuary wetland, and the ecological conditions of the lower reaches of the Yellow River and the estuary delta have continued to improve



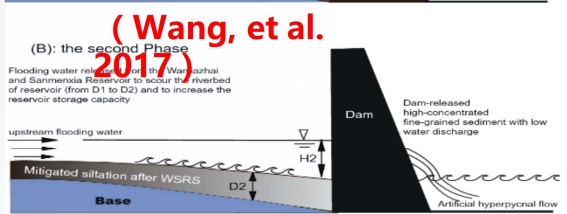
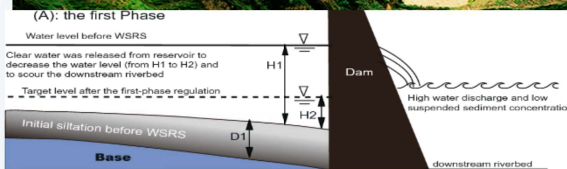
- **Water and sediment regulation is necessary for a long time in future.** The fundamental nature of the disharmonious relationship between water and sediment in the Yellow River has not changed, and water and sediment regulation is an important measure to maintain the healthy life of the Yellow River, which needs to be carried out for a long time in the future.
- **Key parameters need to be optimized and adjusted in time.** In order to improve the efficiency of sediment transport per unit of water volume, the key parameters of water and sediment regulation need to be timely adjusted according to the situation of incoming water and sediment, the boundary of reservoirs and river channels, and need the continuous support of scientific research.
- **Comprehensive measures are also important.** In the Yellow River basin, where water resources are in serious shortage, the water used for sediment transport is restricted in all aspects, and comprehensive measures should be taken to deal with the disharmony of water and sediment in the Yellow River.



(Fu, et al. 2023)



(Cai, et al. 2022)



(Wang, et al. 2017)



Prototype Yellow River



Model Yellow River



Digital Twin Yellow River



**Thanks for your
Attention!**