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Research paper

Coarse sediment and lower Yellow River siltation

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Abstract

Trap sediment by reservoirs has been effective in protecting the Lower Yellow River (LYR) but it can hard be sustainable. After reviewing the nature of sediment and siltation, the effect of coarse sediment ($d > 0.08-0.1$ mm) (CS) on LYR siltation is studied. It is basically proved that the CS was apt to aggregate in special reach in the upmost fluctuating backwater of reservoirs due to the effect of hydraulic sorting; persistent dredging here in a fixed dredging basin (FDB) can remove most CS and prevent it from entering the LYR. It is thus possible to ease or to cease LYR siltation. Removing CS has also proved to be able to save reservoir capacity (Zhou et al., 2010). Therefore, previously projected temporary trapping storages as the Xiaolangdi reservoir (XLDR) immediately upstream of LYR can be adjusted with new role to screen CS. The LYR can be protected without needing more dams.

Keywords: Lower Yellow River; Siltation; Coarse sediment; Sorting; Dredging

1. Background

Starting from the piedmont of Mt. Bayanhar in west China, the Yellow River (YR) extends 5464 km with a catchment of 7.52×10^5 km^2 across the Loess Plateau of the most erodible soil on Earth and delivers 1.6×10^9 t/yr sediment with only 3.85×10^{10} m^3/yr runoff (Fig. 1). The LYR 800 km from Zhengzhou to estuary perches 4–6 m or more than 10 m in some parts above ground. Sedimentation makes the LYR vulnerable and dangerous as it is easy to silt, to breach and to migrate its courses. Historically, it shifted across the North China Plain and brought the land with long last hazards, famines and poverties again and again. LYR continuous siltation by heavy sediment is an unsolved problem.

Since the Holocene as the Earth cooled and more intensified by human activities, heavy soil loss from the Loess Plateau led LYR extension and rise. It was estimated that silt had the land surface the LYR goes piled up by 35.6 m in past 12,000 years (Qian et al., 1993). Since 1194, deposition was mainly concentrated along the courses that shifted in south and north of Shandong province (Fig. 1). The old LYR, called as Ming-Qing course, existed 661years from Song to Qing dynasty, rose 18 m in 600 km from Dongbatou, the great breach happened in 1855, to the estuary at Yellow Sea, while the current course, rose 18 m again in only 150 years. Rise rate in five different periods indicates an increasing tendency (Fig. 2).

The hydrology and depositions of the LYR in past 60 years is indicated in Fig. 3. In this period, levees along LYR were raised and enforced for 4 times. High embankment protected the LYR without inundations; however, it bounded all sediment and caused the river the largest rate of rise (16 cm/yr) in the 1950s. Since 1960, reservoirs and many small silt-dams were built successively across the basins and sediment was significantly trapped behind dams. The reservoir Sanmenxia (SMXR) that used to be the biggest in China trapped 4.45×10^9 m^3 sediment in only 4years from 1961 to 1964 and 7.2×10^9 m^3 up to 1999. Serious deposition caused the lower Weihe, a big tributary in its pool limit, 5 m above ground and raised flood stages even endangering the metropolis Xian. In

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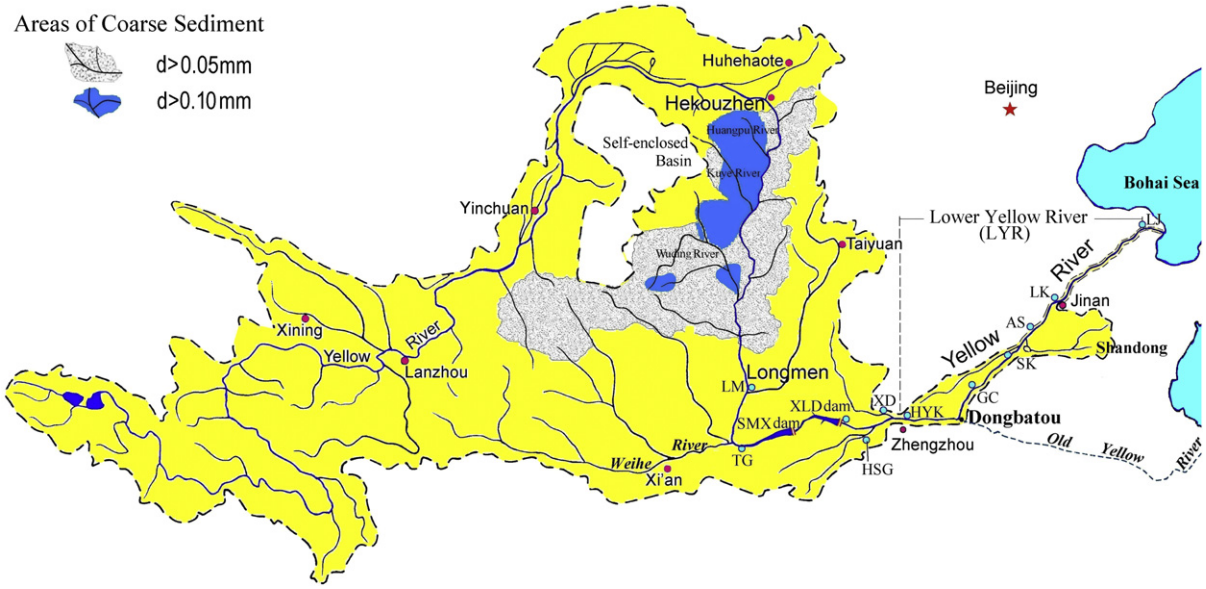

Fig. 1. Illustration of the YR basin and source areas of coarse sediment in middle YR. LM, TG, SMX, XLD, HYK, GC, SK, AS, LK, LJ, HSG and XD are abbreviations for the gauge stations along YR.

addition to so much loss, the LYR after 1964 still deposited 6.5×10^9 m^3 and silted at an average rate 12 cm/yr (Qian et al., 1993). To protect the LYR, XLDR was impounded in 1999 as successor of SMXR. The XLDR sluiced only 16% sediment that is less than 1×10^8 t/yr and much less than the sluice rate of SMXR (39.4%) in 1961–1964. It already trapped 2.42×10^9 m^3 sediment up to 2008. Moreover, prolonged dry decades seriously shrunk the river that raised the main channel far above flood plains as secondary suspended river. As trapping storages is only effective shortly; fewer and fewer sites are available for reservoirs, the future of LYR can hard rely on dams.

2. Roles of coarse sediment on LYR siltation

Logically, LYR siltation is caused by heavy sediment. But, saying accurately, it is caused by coarse sediment. Chien et al. (1980) proved that LYR deposition was caused by the so called harmful particles of $d > 0.05$ mm that came from few tributaries as Huangpu, Kuye, Wuding and others in the

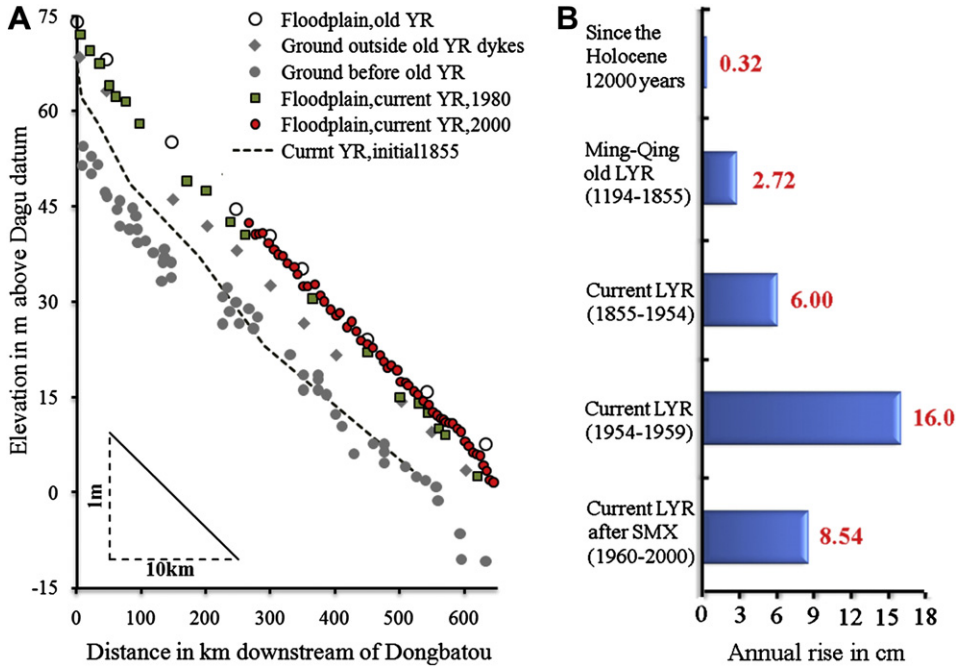

Fig. 2. Historical siltation of the LYR. A: Observed longitudinal profiles of the old and current LYR downstream Dongbatou (after Zhang and Xie, 1985); B: Siltation rates of LYR in 5 different periods in history.