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Sediment rating parameters and their implications: Yangtze River, China

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Abstract

This study examines the characteristics of sediment rating parameters recorded at various gauging stations in the Yangtze Basin in relation to their controls. Our findings indicate that the parameters are associated with river channel morphology of the selected reaches. High *b*-values (>1.600) and low log(*a*) values (<−4.000) occur in the upper course of the steep rock-confined river, characterizing high unit stream power flows. Low *b*-values (<0.900) and high log(*a*) values (>−1.000) occur in the middle and lower Yangtze River associated with meandering reaches over low gradients, and can be taken to imply aggradation in these reaches with low stream power. Higher *b*-values (0.900–1.600) and lower log(*a*)-values (−4.000 to −1.000) characterize the reaches between Yichang and Xinchang, immediately below the Three Gorges. These values indicate channel erosion and bed instability that result from changes in channel gradient from the upstream steep valley to downstream low slope flood plain settings. Differences in channel morphology accompany these changes. Confined, V-shaped valleys occur upstream and are replaced downstream by broad U-shaped channels. The middle and lower Yangtze shows an apparent increase in channel instability over the past 40 years. This inference is based on sediment rating parameters from various gauging stations that record increasing *b*-values against decreasing log(*a*)-values over that time. Analysis of the sediment load data also reveals a strong correlation between changes in sediment rating curve parameters and reduction of annual sediment budget (4.70×10^8 t to 3.50×10^8 t/year, from the 1950s to 1990s), largely due to the damming of the Yangtze and sediment load depletion through siltation in the Dongting Lake. Short-term deviations from the general trends in the sediment rating parameters are related to hydroclimatic events. Extreme low *b*-values and high log(*a*)-values signify the major flood years, while the reverse indicates drought events. When compared with rivers from other climate settings, it is evident that the wide range of values of the Yangtze rating parameters reflects the huge discharge driven by the monsoon precipitation regime of eastern China.

Keywords: Riverbed erosion and siltation; Hydromorphology; Monsoon climate; Sediment rating parameter; Sediment transport; Yangtze River

1. Introduction

During recent decades, river erosion and sedimentation have been linked to questions of variations in fluvial sediment transport and sediment flux (Vansinckle and Beschta, 1983; Fenn et al., 1985; Ferguson, 1986; Milliman

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and Syvitski, 1992; Miller and Gupta, 1999; Chen et al., 2001a; Zhao and Chen, 2003). Riverbed stability and its significance as a factor in sediment yield and transport estimates have been evaluated over time and space (Belperio, 1979; Ferguson, 1987; Jansson, 1996; Córdpva and González, 1997; Moog and Whiting, 1998; Whiting et al., 1999; Asselman, 1999, 2000; Syvitski et al., 2000; Horowitz, 2003; Morehead et al., 2003; Simon et al., 2004).

The sediment rating curve is defined as the statistical relationship between suspended sediment concentration (SSC) or sediment load (Q_s) and stream discharge (Q). The relationship generally takes the form of a power function, although other types of relationships have also been advocated (Syvitski et al., 1987; Córdpva and González, 1997). The general relationship between Q and SSC is expressed as:

$$\log SSC = \log a + b \log Q$$

Asselman (2000) argued that the parameters a and b in the sediment rating curve contain no particular physical meaning. Other studies see the sediment rating parameter a as an index of erosion severity in the river channel (Peters-Kümmerly, 1973; Morgan, 1995). Usually, high a-values occur in areas characterized by easily eroded and transported materials. The rating parameter b is taken to depict the erosive power of the river. Large values are thought to be indicative of rivers that show a strong increase in entrainment and transport with increasing discharge. However, b can also reflect the extent to which new sediment sources become available when discharge increases (Asselman, 2000). According to Walling (1974), b-values can be affected by the grain-size distribution of the material available for transport. Syvitski et al. (2000) stated that in North American rivers the sediment rating parameters are often influenced by sediment rating, erosion and climate.

Due to the inverse correlation between $\log(a)$ and b-values of the sediment rating curve, it has been suggested that a combination of the $\log(a)$ and b-values may act as a measure of soil erodibility and erosivity (Rannie, 1978; Thomas, 1988; Asselman, 2000). Steep rating

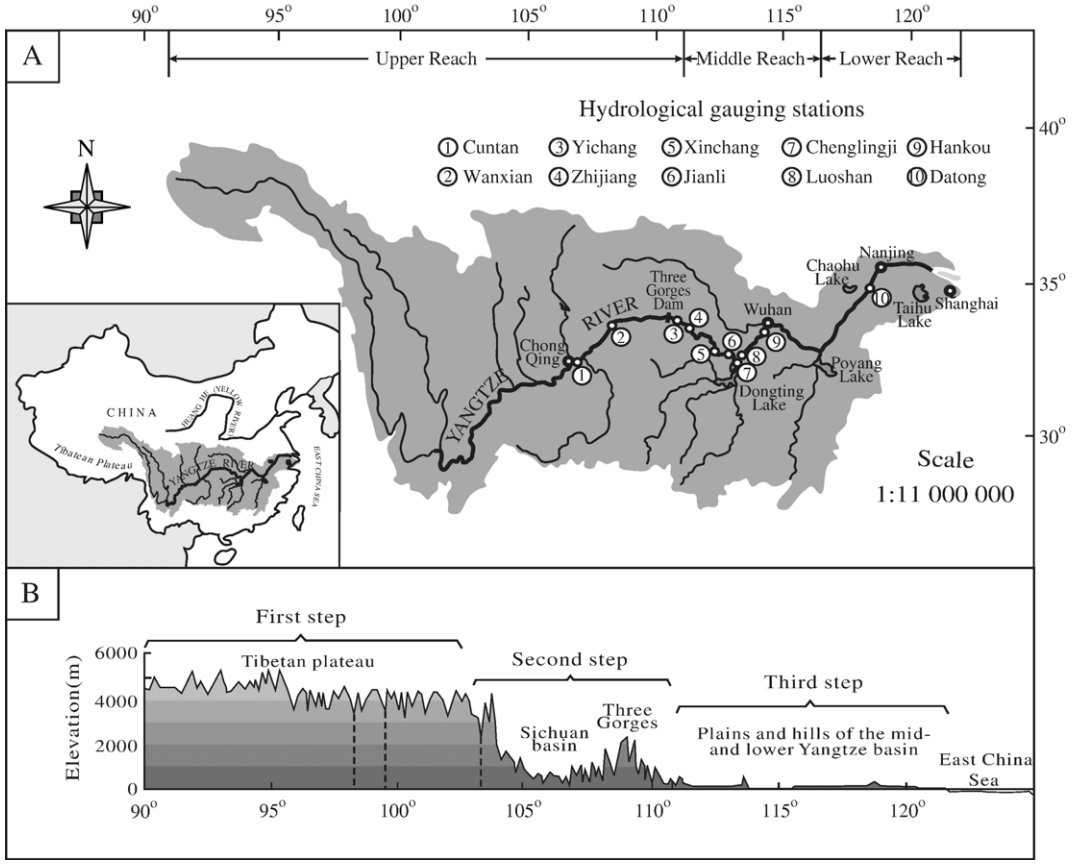

Fig. 1. A. Sketch map of Yangtze drainage basin showing ten gauging stations selected for the present study and Dongting Lake of the middle Yangtze Basin; B. Three morphological levels of the basin.