When Does the Dominant Discharge Concept in Rivers Apply? A Sediment Yield Perspective

1 Overview

What flow or range of flows is most responsible for transporting sediment and maintaining continuity in a river? This question has inspired scores of studies on the magnitude and frequency of sediment transport analysis (MFSA) studies and is central to defining dominant discharge.

I consider how the Sediment Yield Spread of a given river is influenced by the size of its bed material and the variability of its flow regime. Sediment Yield Spread quantifies the relative width of the range of flows responsible for the middle 50% of cumulative sediment yield in a river.

2 Methods

I conducted magnitude-frequency analysis on 153 stream sites with existing bed material load data collected near a stream gauge. I stratified these sites by coarse bed, bed load-dominated and fine bed, suspended load-dominated streams. I used a bias-corrected, log-linear regression to create a power law sediment rating curve of the form Qs = αDβ (Figure 3). Sediment yield metrics such as the most effective discharge (Qeff), the half-yield discharge (Qh), the half-yield discharge (Qh) Grey lines represent smoothed LOESS lines. Here I take the morphological bankfull discharge, Qbf as the dominant discharge and compare other sediment yield-based dominant discharge metrics with Qbf, Qs and Qh. I find that Yield Spread increases, Qbf become much smaller relative to Qs and that the value of Qs relative to Qbf does not vary.

The dominant discharge concept applies where Yield Spread is relatively small, i.e., where Qs ≈ Qbf. Note that Qs best predicts Qbf in fine bed rivers compared to Qbf as well as hydrologic predictors (e.g., the 1.5 year return interval flood) (Sholtes and Bledsoe, 2013).

3 Defining Dominant Discharge

The dominant discharge is a theoretical value that, if held steadily over time, would result in the same observed channel form and slope under the existing sediment supply (question and cell). It is defined in a number of ways, recently reviewed by Blom et al. (2017). The variability of the flow regime along with the size of the bed material are two primary factors that influence the range and magnitude of flows responsible for sediment continuing in a river.

Rivers with coarse bed material typically transport the majority of their sediment load at discharge at or near bankfull where the threshold for entrainment is passed (Phillips & Jerolmack, 2008). Rivers with finer bed material transport their sediment load over a much broader range of discharges. Sediment continuity in fine bed rivers relies on flow ranging from well below bankfull to well above.

4 Linking Sediment Yield with Dominant Discharge

Yield Spread plotted as a function of D50 and CV based on a theoretical channel with grain sizes and even begins to decrease for CV > 2.5. The theoretical maximum of Yield Spread increases with increasing CV and finer bed fine gravel and sand) material load transport sediment across all flow.

Rivers with greater flow variability and finer bed fine gravel and sand) material load transport sediment across all flow.

5 Theoretical Relations

Yield Spread increases with D50 in fine bed rivers and then decreases with D50 in coarse bed rivers, with a peak in the coarse sand to the very fine gravel range. Note that the D50 of fine bed sites increases with flow variability.

6 Take Home Points

1. Sediment Yield Spread quantifies the relative width of the range of flows responsible for the middle 50% of cumulative sediment yield in a river.

2. As a river’s bed material decreases in size, a wider range of flows are responsible for transporting sediment (Yield Spread increases).

3. Yield Spread increases with flow regime variability (CV), especially in fine bed rivers.

4. The ratio of Qs to Qbf increases with increasing Yield Spread, but is approximately unity for Qs/Qbf regardless of Yield Spread.

5. The dominant discharge concept applies to streams with coarser bed material load and lower flow variability. Whereas river with greater flow variability and finer bed fine gravel and sand) material load transport sediment across all flow.

6. Streams with fine beds are more sensitive to changes in flow and sediment regimes brought on by environmental change.

7 References


