Two-dimensional modeling of variable-width gravel bed morphodynamics

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INTRODUCTION

- Natural rivers are often characterized by downstream, sometimes periodic, variations in channel width
- Width variations are often coincident with other channel features (e.g., meandering, braiding index)
- Width variations are often considered forcing factors for in-channel geomorphic units (e.g., riffles and pools)
- Riffles and pool locations have been observed to be controlled by variations in bankfull channel width

- How do width variations affect bed topography (bar configuration), grain-size sorting, and sediment pulse evolution?
- What are the effects of unsteady flow and sediment supply on bed morphology and grain-size sorting in variable width channels?

METHODS

- Two-dimensional depth-averaged modeling in Delft3D
- Seventeen geometries (1 constant width; 16 variable)
- Sinusoidal width variations (Fig. 1)

$$B(x) = B_0[1+A_c\sin(\lambda_c x B_0^{-1})]$$

- Vary amplitude (A_c) and wavenumber (λ_c)

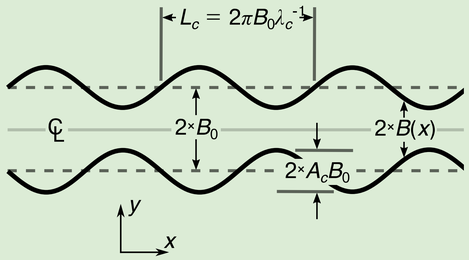

Figure 1. General planform geometry of variable width channels

- A_c = [0.1, 0.2, 0.3, 0.4]; λ_c = [0.2, 0.4, 0.6, 0.8]
- Riffle-pool spacing (5-7 channel widths) corresponds to wavenumbers ranging from 0.45-0.62
- Amplitudes for riffle-pool width variations are generally 0.07-0.14, although can be as high as 0.33-0.43
- Ten series of runs (Fig. 2); (un)steady flow (Fig. 3)
- Bedload calculated using Wilcock-Crowe formula
- Grain size distribution of coarse sand to medium gravel
- dx = dy = 5.44 cm
- dt = 0.005 sec

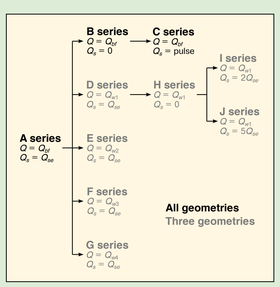

Figure 2. Numerical experimental procedure, showing the sequential order of dependant series.

RESULTS

- Bar configuration (central or side bars) controlled by wavenumber of width variations (Fig. 4, 5, and 6).

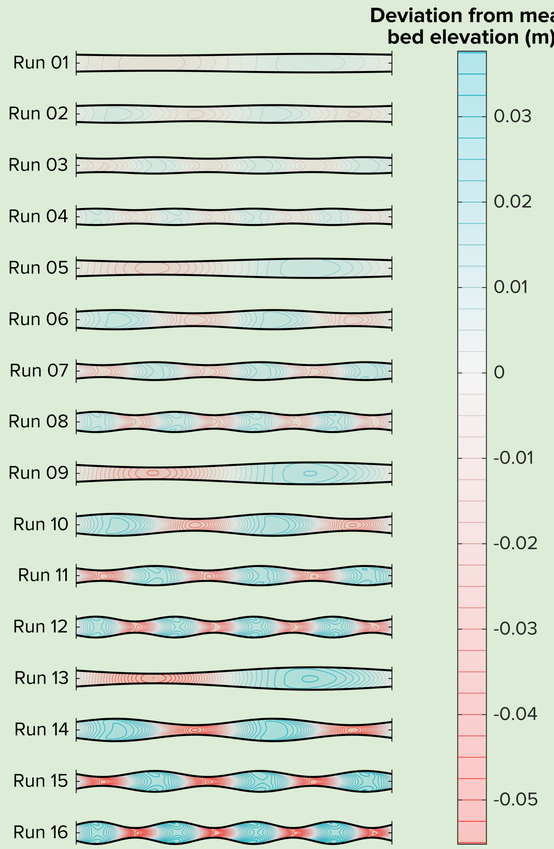

Figure 4. Detrended elevation maps for A-series. Vertical exaggeration of 10. Contour intervals of 2.5 mm.

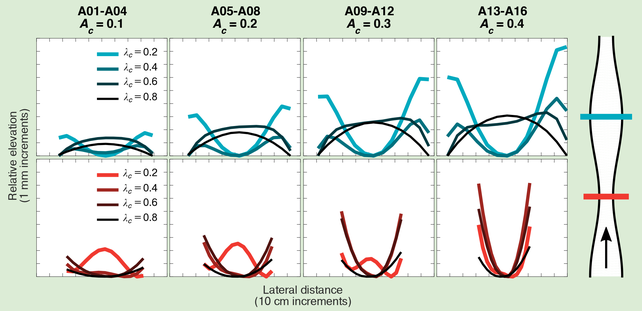

Figure 5. Cross-section profiles of the widest/narrowest channel sections from the A-Series final states. Vertical exaggeration of 100.

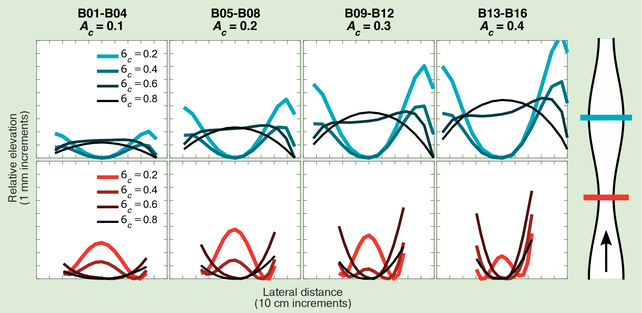

Figure 6. Cross-section profiles of the widest/narrowest channel sections from the B-Series final states. Vertical exaggeration of 100.

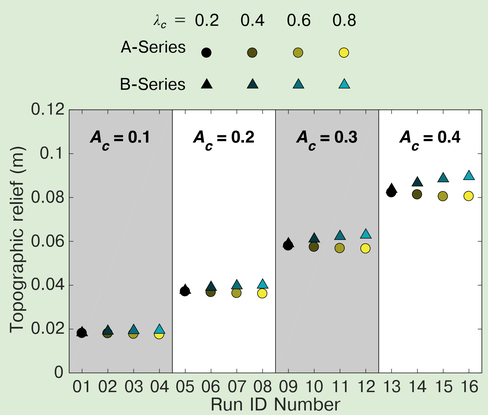

Figure 7. Topographic relief between cross-sectional mean elevation in locations of maximum and minimum channel width.

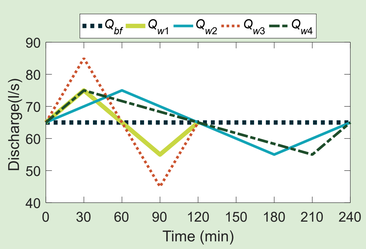

Figure 3. Unsteady flow hydrographs

- Amplitude of width variations controls the relative topographic relief between areas of wide and narrow channel width (Fig. 4 and 7)
- Slight increase in topographic relief from equilibrium sediment supply to no sediment supply (Fig. 7)
- Wavenumber plays little role in topographic relief, although higher values (shorter wavelengths) show greater change between supply and no supply conditions
- Numerical simulations are ongoing (sediment pulse and unsteady flow runs have yet to be completed)

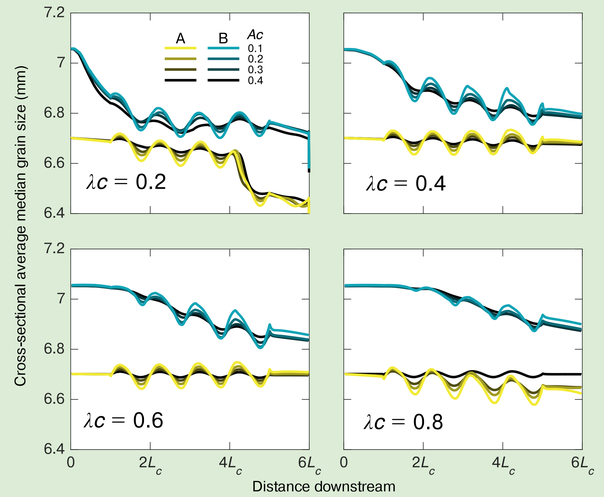

Figure 8. Longitudinal profiles of cross-sectional average median grain diameter.

- Grain size patterns generally coincident with variations in channel width, although very small magnitude (< 1 mm)

RELATED/FUTURE WORK

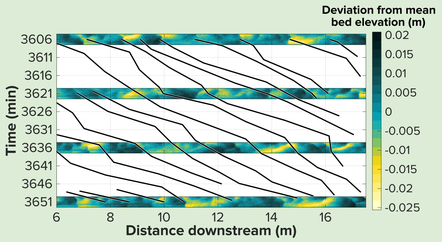

Figure 9. Gravel bedform migration in a straight-walled flume

- Ongoing physical flume experiments
- One straight-walled, one variable width

- Straight-walled runs are completed
- Complex 3D gravel dunes at equilibrium sediment supply (Fig. 9)
- Alternating bedforms at 2 x equilibrium sediment supply and unsteady flow (Fig. 10)
- Variable-width to come

Figure 10. Bedforms at high sediment supply organized into alternating pattern. Not long enough to be alternate bars?