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@DWhit_Geo

Hydraulic Geometry of 'Equilibrium' Channels: from Theory to Application at the National Scale

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(1) Background and Aim

Gravel bed rivers **adjust their geometry in response to changes (or pulses of change) in sediment supply and hydrology**. These adjustments tend towards a quasi-stable equilibrium channel, where sediment supply and bed mobility are approximately in balance [1,2].

Understanding the processes that drive changes in channel morphology is important in **predicting future changes in channel capacity and flood risk** under climate change, on national scales [3, 4].

Previous flume and field studies have sought to quantify channel disequilibrium, and explored likely equilibrium dimensions for stable channels. However, the geological, hydrological and biological **sensitivities that control channel response are complex** [2,5].

Aim: Ground truth channel geometry theories, and explore their usefulness in identifying channels susceptable to aggradation/degradation at a national scale.

(2) Methods: Quantifying Channel (Dis)Equilibrium

Hydraulic Geometry [6, 7]

Equilibrium Width: $H_{bf} = \frac{1.2\tau_c}{\rho g S}$

Equilibrium Depth: $W_{bf} = \frac{Q_{bf} S}{C_f g^{1/2} \left(\frac{1.2\tau_c}{\rho g}\right)}$

Threshold Theory [8]

Lacey's Law: $\frac{W}{D_{50}} = \left[\frac{\pi}{\sqrt{\mu}}\left(\frac{\tau^*_c(\rho_s - \rho_w)}{\rho_w}\right)^{-0.25}\sqrt{\frac{3C_f}{2^{1.5}K(0.5)}}\right] Q_*^{0.5}$

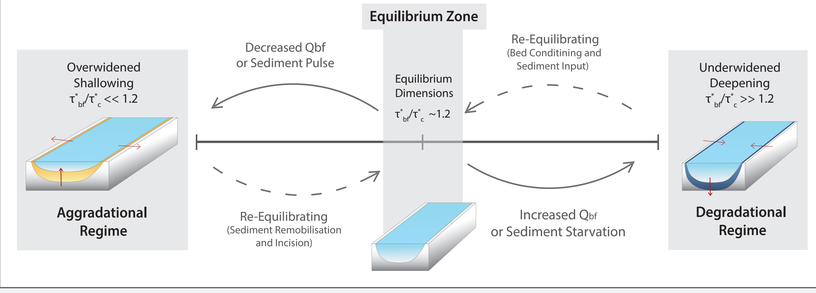
Shear Stress Ratio [9, 10, 11]

τ^*_{bf}/τ^*_c

$\tau^*_{bf} = \frac{R_{bf} S}{\left(\frac{\rho_s}{\rho_w} - 1\right) D_{50}}$

$\tau^*_c = 0.15\, S^{0.25}$

Interpreting Deviations from Equilibrium Theory



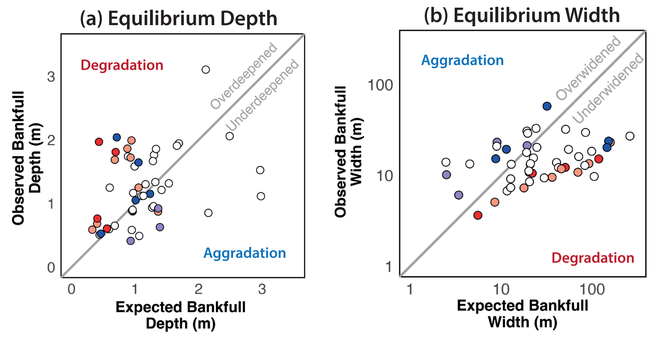
Each method field-validated at 50 sites across the UK

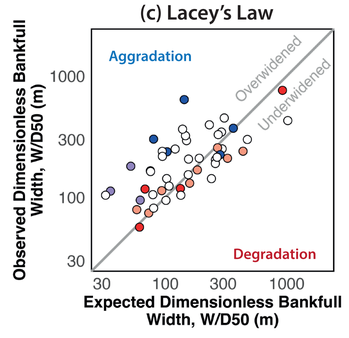
Are deviations from these expected equilibrium conditions reflected in contemporary field observations?

Field Observation: Metrics of Observed Equilibrium State

Aggradation 2, 1 — Equilibrium 0 — Degradation -1, -2

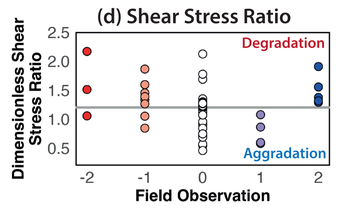
(3) Results: Deviations from Equilibrium Geometry





Observed vs expected geometry predicted by (a-b) Hydraulic Geometry, (c) Threshold Theory and (d) Shear Stress Ratio. Channels which deviate from equilibrium conditions (grey line) are interpreted as aggraded or degraded systems, annotated on each diagram. Points coloured by field observation.

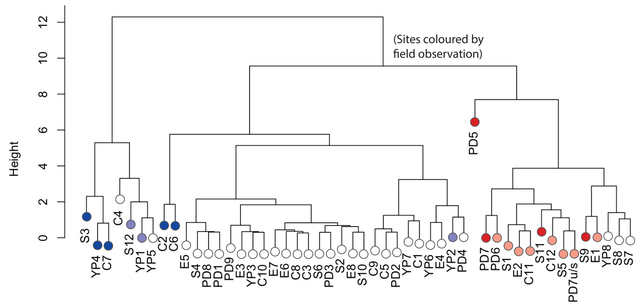
Field Observation (Evidence of Contemporary Change): 2 Aggradational, 1, 0 Equilibrium, -1, -2 Degradational



(4) Do All Approaches Agree?

Cluster analysis of % deviation from expected equilibrium conditions, for each of 5 methods:

Hydraulic Geometry Width (i) and Depth (ii); Lacey's Law (iii); Shear Stress Ratio (iv); Field Observation (v)



Aggradational (All, or most theories agree)

Zone of Uncertainty (~68% of Sites) Are these sites actually at equilibrium, or do the theories just disagree?

Degradational (All, or most theories agree)

The Problem: Sites most vulnerable to change are likely those in the centre, where field evidence for aggradation/degradation is limited, and theories contradict each other

(5) Conclusions

Hydraulic geometry and threshold theories are generally effective at identifying sites experiencing most significant extents of aggradation/degradation

However

(a) There are many stable (observed) sites that deviate from their theoretical equilibrium conditions

(b) Actively aggrading sites do not necessarily have low shear stress ratios

(c) The theories do not always agree... how do we know which to trust?

(6) New Questions, Next Steps

(a) Which channel characteristics (confinement, geology, vegetation) most influence the uncertainty of hydraulic geometry theory?

(b) How sensitive are 'equilibrium' channels to subtle changes in:
Channel Hydrology (τ^*_{bf})
Bed Mobility (τ^*_c)

(c) How do these sensitivities vary at different spatial and temporal scales?

References:

Loughborough University · Natural Environment Research Council · BSG British Society for Geomorphology · Environment Agency