The Biophysical Template for River Corridor Resilience

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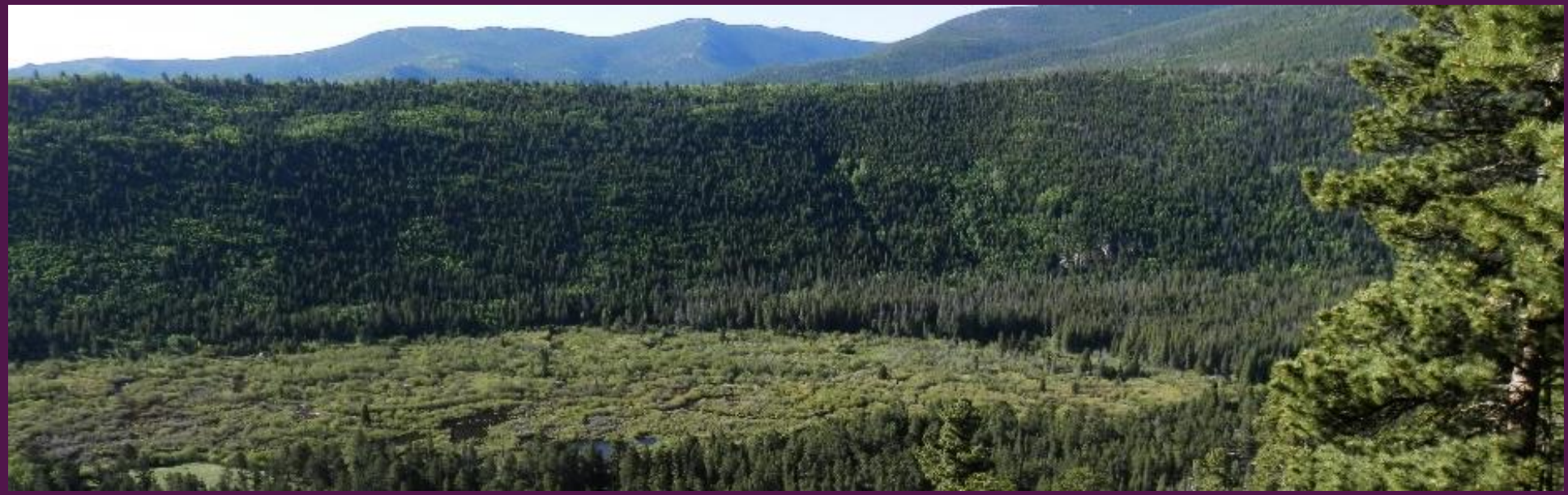
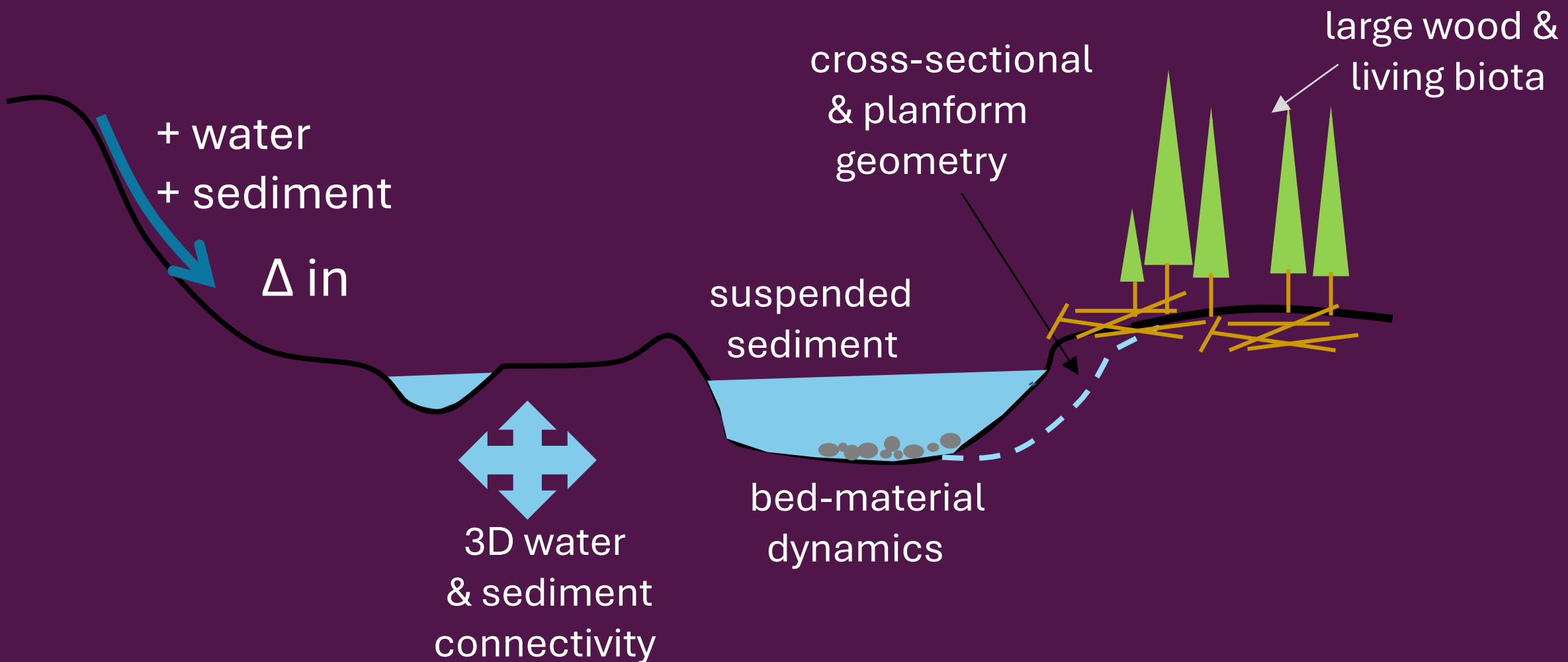
Resilience: the ability to recover to pre-disturbance conditions
continuum dependent on time & space (not binary)



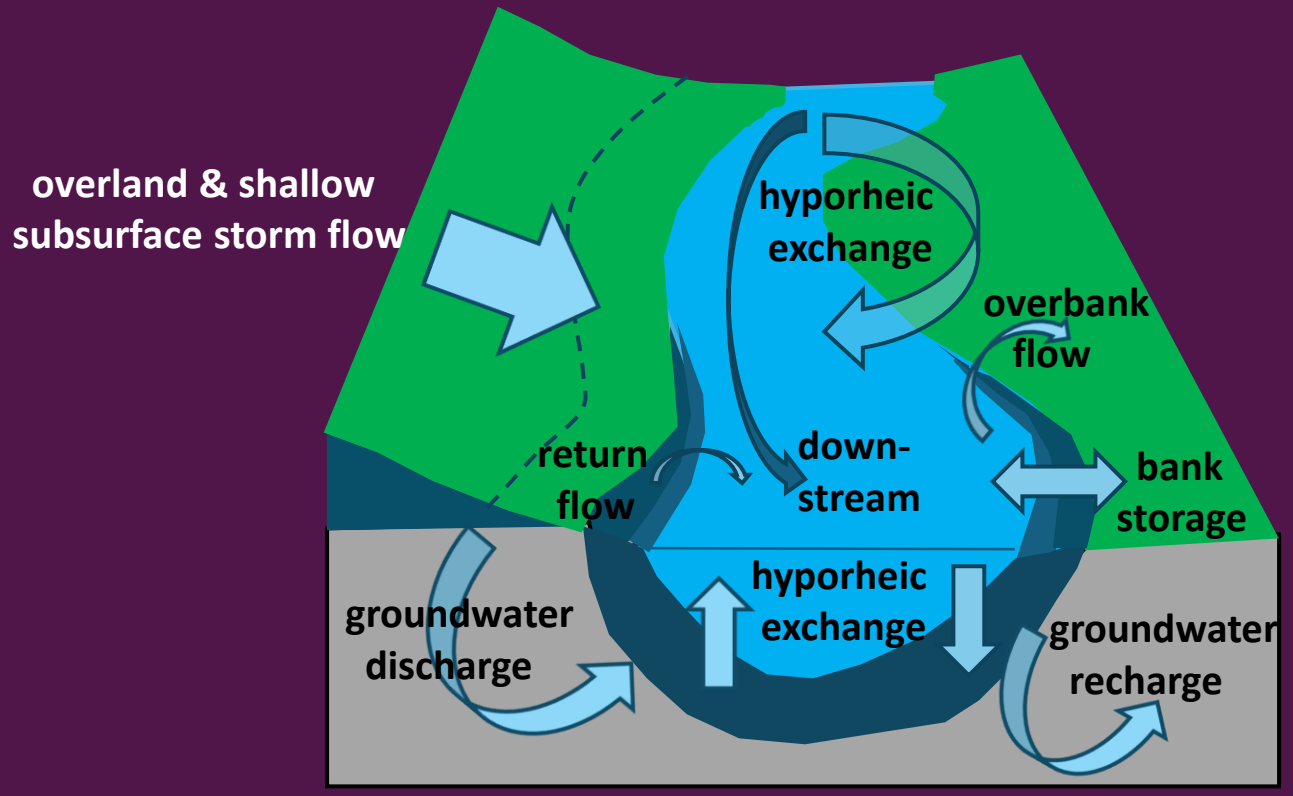
Disturbance: an episodic or continuous extreme event
(e.g., wildfire followed by flood & debris flow)
disturbance cascade = increased water + sediment inputs & secondary effects



River corridor

active channel(s), floodplain, hyporheic zone

system of individual components with different levels of resilience



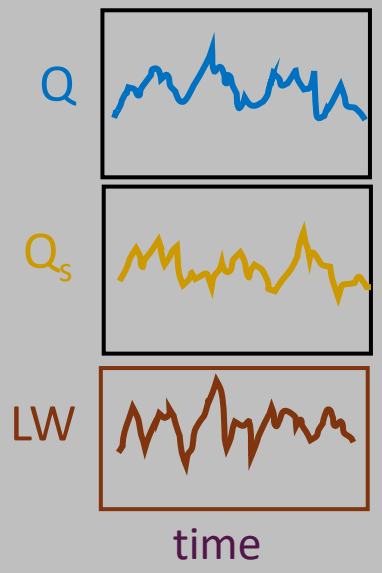
water & solutes

Harvey & Gooseff, 2015,
Water Resources Research

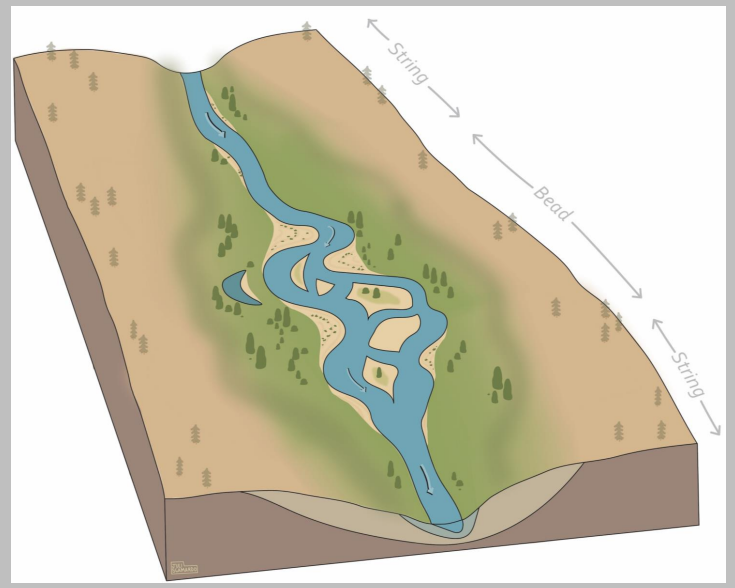
River corridor = reach scale (10^1-10^3 m lengths)

Reach-scale influences on resilience

Configuration & stability of river corridor



flow, sediment, & large wood regimes



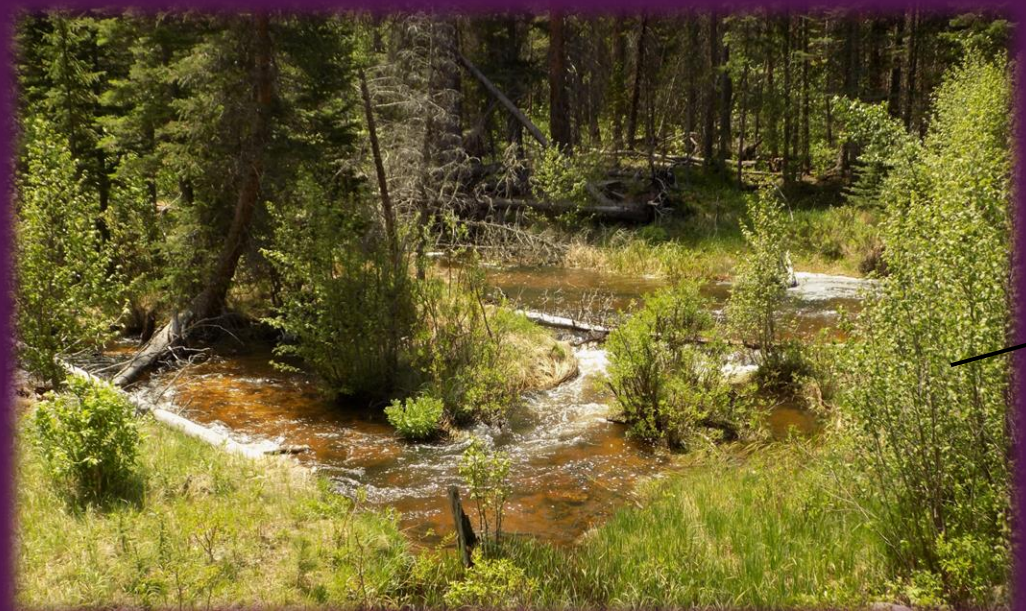
valley floor lateral confinement & gradient → spatial heterogeneity

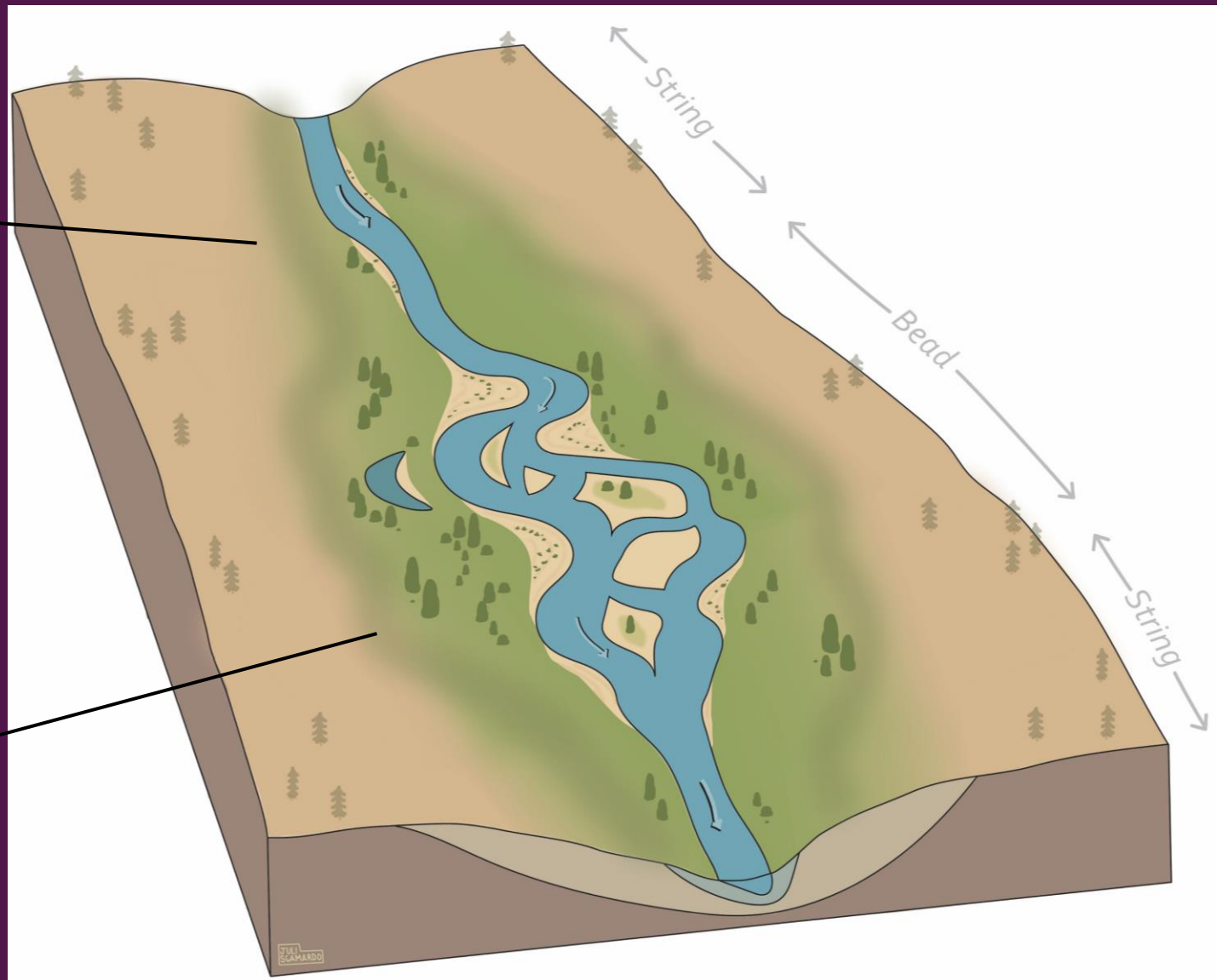
biota

Space to adjust (attenuation of fluxes)

Ability to adjust (feedbacks)

single-thread to anastomosing channel downstream alternating beads & strings





The example of Little Beaver Creek, Colorado

Drainage area 40 km^2
Forested: logjams & old beaver dams
Streamflow: snowmelt with summer
convective storms
Wildfire in 2020
Floods in 2021 & 2022

2021 edition

wide, low gradient reaches

old beaver-dam berm traps wood → channel-spanning logjam

logjam backwater stores sediment & jam promotes overbank flow, secondary channels, & hyporheic exchange flow

higher water table & sediment deposition promote floodplain re-vegetation

beaver return & build new dams

SPATIAL HETEROGENEITY → RESILIENCE

Wohl et al., 2022,
Science of the Total Environment

2022 edition

persistent lateral connectivity enhances floodplain erosional resistance & attenuates downstream fluxes

floodplain jams create ecological subsidy via habitat & nutrients

Logjams force channel avulsion & formation of floodplain knickpoints & anastomosing channels

beaver berms & floodplain vegetation→ floodplain logjams in beads

wide, low gradient reaches

narrow reaches

channel erosion

entire floodplain inundated

SPATIAL HETEROGENEITY → RESILIENCE

Wohl et al., 2024, Geomorphology

Valley segments with less lateral confinement & greater spatial heterogeneity most effectively attenuate downstream fluxes of post-fire water & sediment inputs (12% of total valley length, but 25% of total sediment storage in 2021) –

sediment & OM storage in backwaters, secondary channels, on floodplain
water storage in backwaters, secondary channels, floodplain, & hyporheic

Attenuating sediment fluxes reduces phosphate inputs downstream
Hyporheic exchange & backwater storage enhance denitrification nitrate uptake

Management & restoration that foster spatial heterogeneity within selected reaches can enhance resilience to disturbance cascade

Geologically induced spatial heterogeneity of beads & strings

Biophysically induced spatial heterogeneity within beads

Attenuation of downstream fluxes & greater resilience to post-fire disturbance cascade at reach- to network-scales

The basic idea of spatial heterogeneity promoting resilience by attenuating downstream fluxes should apply to diverse spatial scales, river corridors, & river networks

Greater spatial heterogeneity commonly equates to reduced longitudinal connectivity & enhanced lateral & vertical connectivity

Forms of spatial heterogeneity

- channel-scale (substrate, bedforms, banks, cross-sectional geometry)
- reach-scale (channel planform, large wood, beaver, vegetation, floodplain wetlands)
- network-scale (longitudinal alternations in valley geometry &/or function)

Fundamentally, we need to

identify

- natural/potential sources & levels of heterogeneity
- processes that create & maintain heterogeneity
- potential thresholds for proportion of network with high heterogeneity

develop management strategies to protect or restore these processes or to ‘jump start’ heterogeneity

role for field-based & remote data collection, conceptual models, & numerical/predictive models