

WATS 5150 – Fluvial Geomorphology

Key Concepts in Fluvial Geomorphology



Reading for this Module

- CHAPTER TWO: Key concepts in river geomorphology

CHAPTER TWO

Key concepts in river geomorphology

Introduction

This chapter outlines a range of concepts and theories about how a river landscape looks, adjusts and evolves. These spatial and temporal concepts build upon each other helping us to frame catchment-scale, system-specific applications that assess geomorphic responses to human disturbance in relation to natural variability. These concepts aid our efforts to read the landscape.

This chapter is structured as follows. First, spatial considerations are reviewed. This starts with an overview of nested hierarchical approaches to analysis of river systems. Imposed and flux boundary conditions that control the range of river character and behaviour are defined and differentiated. Then the complexity of river structure is differentiated in terms of landscape heterogeneity and homogeneity. The final spatial concept outlined here is a summary of landscape (dis)connectivity.

Second, temporal concepts that are used to characterise river systems are appraised. This starts with a synthesis of geologic (cyclic), geomorphic (graded) and engineering (steady-state) timescales. Equilibrium notions developed via negative feedback mechanisms are used to describe geomorphic adjustments around a mean (*characteristic*) state. River behaviour is differentiated from river change: the latter records a shift to a different type of river with a different behavioural regime. These transitions may be brought about by positive feedback mechanisms that breach threshold conditions. Press, pulse and ramp disturbance events are differentiated. Responses to disturbance are assessed in terms of their reaction and relaxation times. These notions are used to discuss prospects for river recovery. Magnitude-frequency relations highlight how geomorphic work and geomorphic effectiveness vary for disturbance events of differing size and recurrence. Variability in landscape sensitivity, among many factors, results in complex responses to disturbance, as landscapes preserve a variable record of past events (termed memory or persistence). Lagged and off-site responses emphasise the

need to explain patterns and rates of geomorphic adjustment at the catchment scale. The principle of equifinality highlights how similar-looking forms may result from different sets of processes.

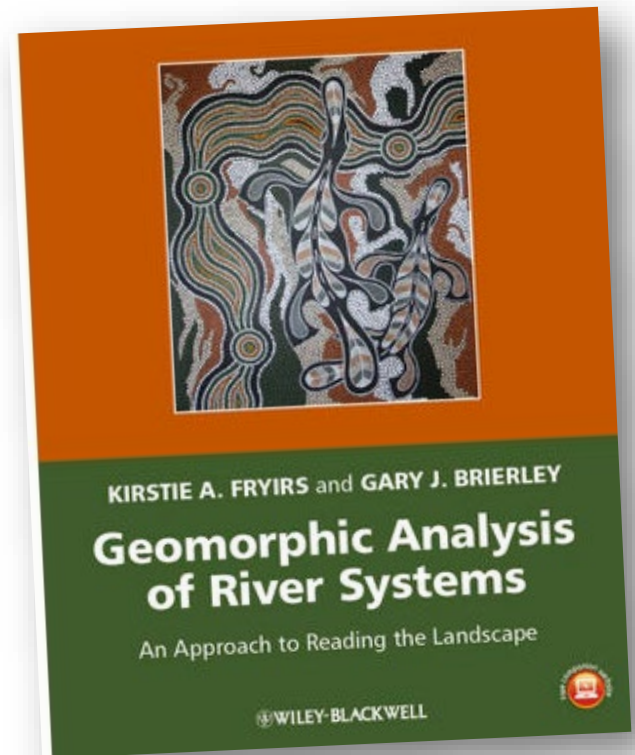
These various spatial and temporal concepts are pulled together in the final section of this chapter. The system-specific configuration of any given catchment, along with its unique history of responses to disturbance, is characterised in relation to non-linear dynamics. Principles of emergence, contingency and path dependency are outlined. System responses to human disturbance are appraised relative to natural variability. Collectively, these considerations frame the evolutionary trajectory of any given system.

Spatial considerations in reading the landscape

Catchments as nested hierarchies: the spatial configuration of landscapes

Nested hierarchical models of catchment organisation frame small-scale (and short-term) river features and processes in relation to larger scale (and longer term) factors (Figure 2.1, Table 2.1). Smaller spatial scales are nested within higher level scales. Each nested level within a hierarchical view of catchments is controlled by the conditions set by higher level scales. This allows interpretation of higher level controls on physical processes that operate at smaller scales.

Different scalar units in the nested hierarchy are commonly not discrete physical entities. Rather, they are part of a complex continuum in which the dimensions of units at each scale may overlap significantly. Interaction between units, at each scale and between scales, determines the character and behaviour of the system under investigation. When used effectively, nested hierarchical frameworks provide an elegant tool with which to organise



- Brierley G and Fryirs K. 2005. *Geomorphology and River Management: Applications of the River Styles Framework*. Blackwell Publishing: Victoria, Australia, 398 pp.

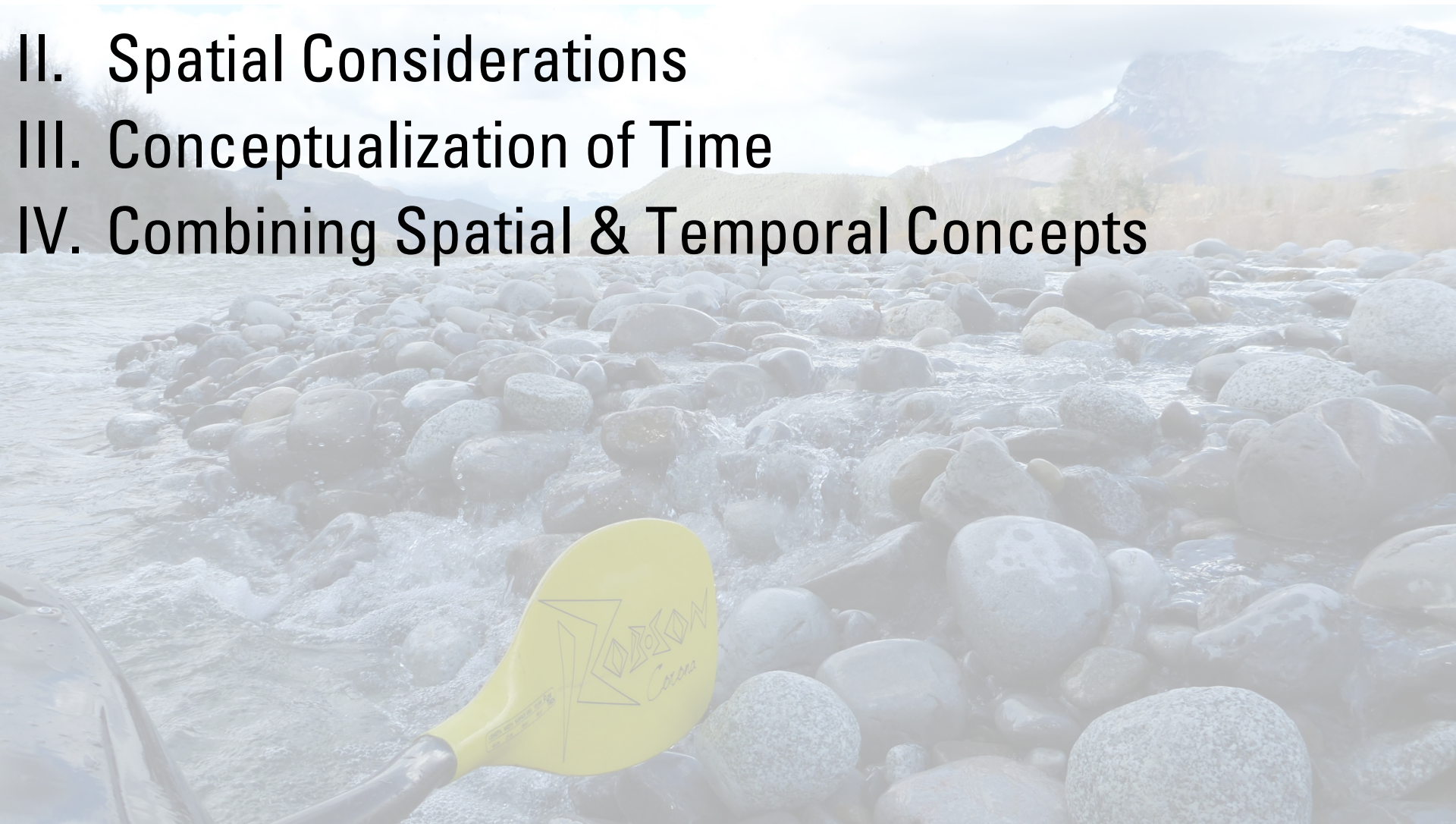
Key Concepts in Fluvial Geomorphology

I. Intro

II. Spatial Considerations

III. Conceptualization of Time

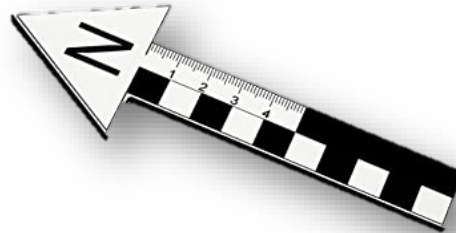
IV. Combining Spatial & Temporal Concepts



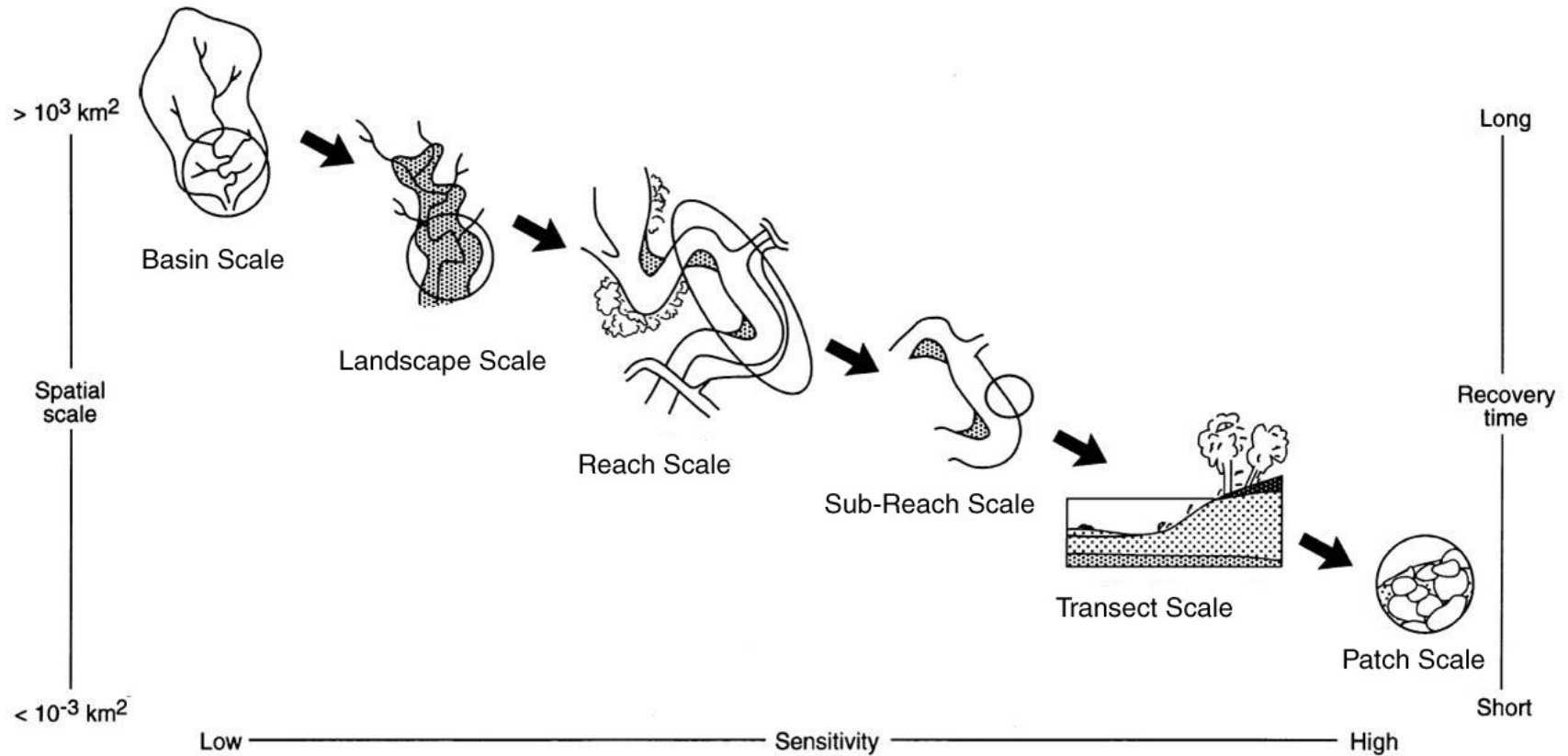


Lecture Purpose

- Define and understand nested **spatial scale** hierarchies
- Understand the classic **temporal concepts** in fluvial geomorphology
- Build appreciation of **space-time relationships**



The Space-Time Assertion & Nested Spatial Scales



Key Concepts in Fluvial Geomorphology

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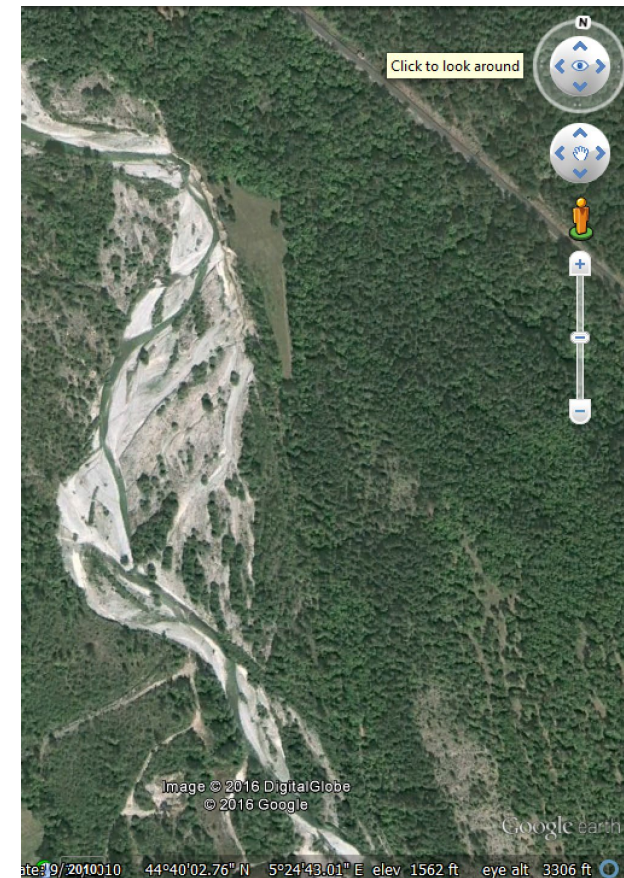
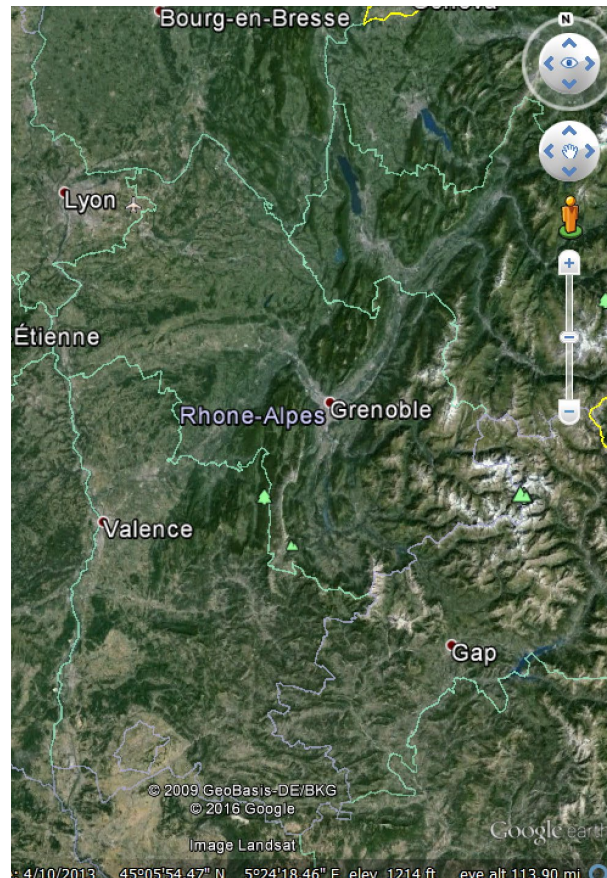
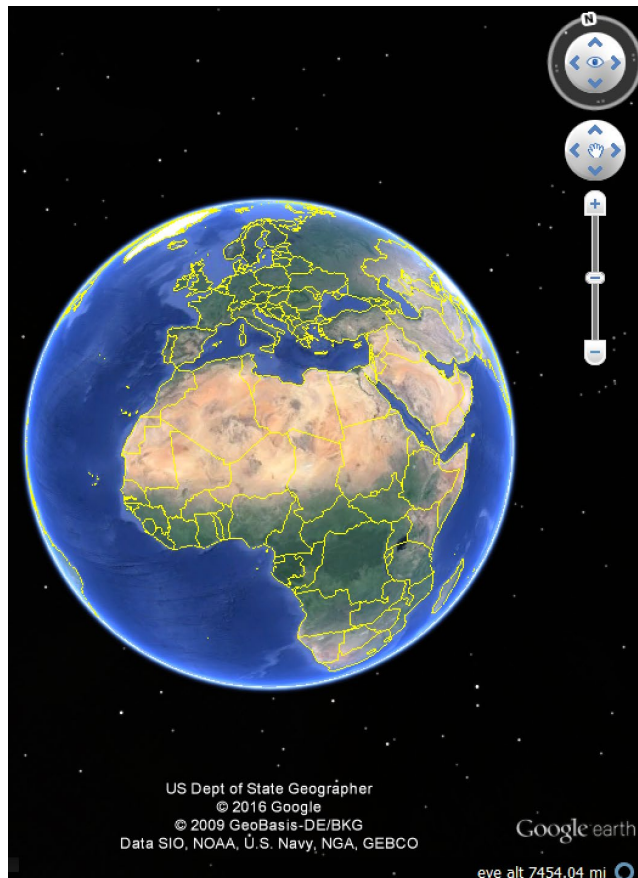
IV. Combining Spatial & Temporal Concepts



Transcending nested spatial scales



What you already do... with your index finger



Let's Be Clear About Spatial Scale...

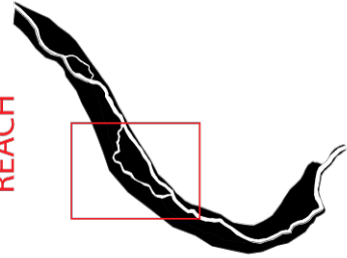
Table 1. Definition of spatial scales used in this paper in terms of extent and resolution

Scale name	Extent	Resolution	GIS representation
Basin Scale	Basin (10^3 to 10^5 km ²)	Basin (10^3 to 10^5 km ²)	Polygon
Sub-Basin Scale	Sub-Basin (10^1 to 10^3 km ²) Sub-Basin (Areal: 10^1 to 10^3 km ² ; Length: 10^4 to 10^8 m)	Sub-Basin (10^1 to 10^3 km ²)	Polygon
Network Scale	Reach (10^2 to 10^3 m)	Reach (10^2 to 10^3 m)	Polyline
Reach Scale	Sub-Basin (10^1 to 10^3 km ²)	Geomorphic Unit (10^0 to 10^2 m)	Raster or Polygon
Sites-on-Network Scale	Reach (10^2 to 10^3 m)	Site Locations (points)	Point
Site-Summary Scale	Reach (20 x Bankfull width; 160 m to 600 m)	Reach (10^2 to 10^3 m)	Point, Polyline or Polygon
Site Scale (CHaMP Reach)	Geomorphic Unit (10^0 to 10^2 m)	Cell (10^{-1} to 10^0 m)	Raster
Geomorphic-Unit Scale	Hydraulic Unit (10^0 to 10^1 m)	Hydraulic Unit (10^0 to 10^1 m) or Cell	Polygon
Hydraulic-Unit Scale	Cell (10^{-1} to 10^0 m)	Grain (10^{-2} to 10^0 m)	Polygon
Cell Scale		Cell (10^{-1} to 10^0 m)	Raster

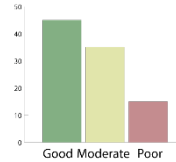
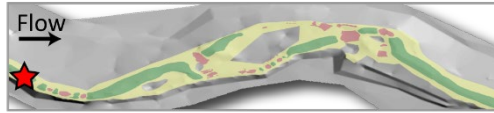
- Defined in terms of extent & resolution
- What spatial scale are you reading at?

The Scale Crux...

REACH



① SITE LEVEL

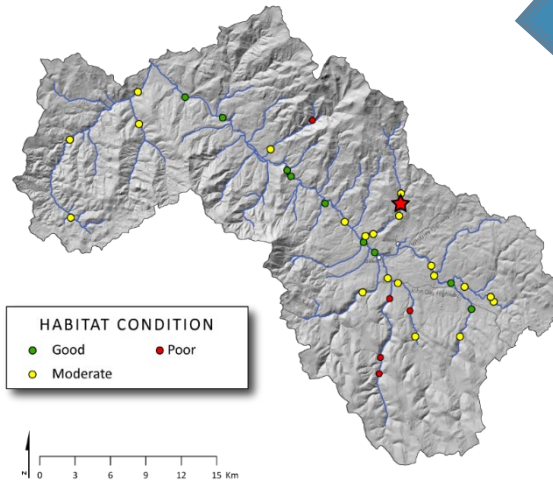


② SITE SUMMARY:



③ SITES ON NETWORK

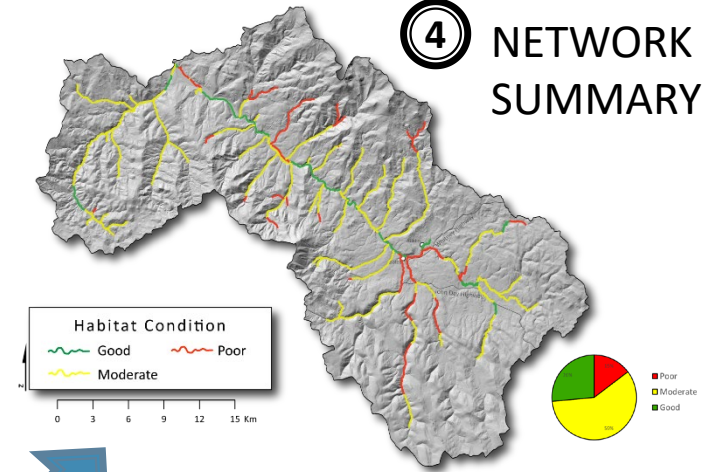
NETWORK



⑤ WATERSHED / POPULATION



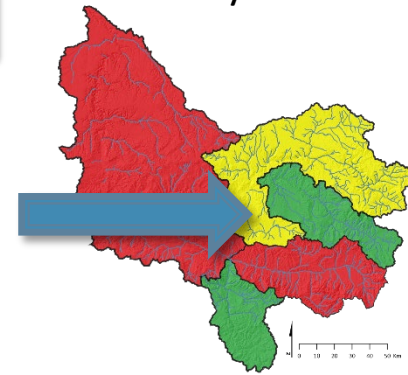
④ NETWORK SUMMARY



BASIN



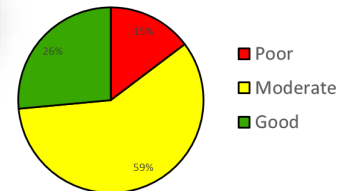
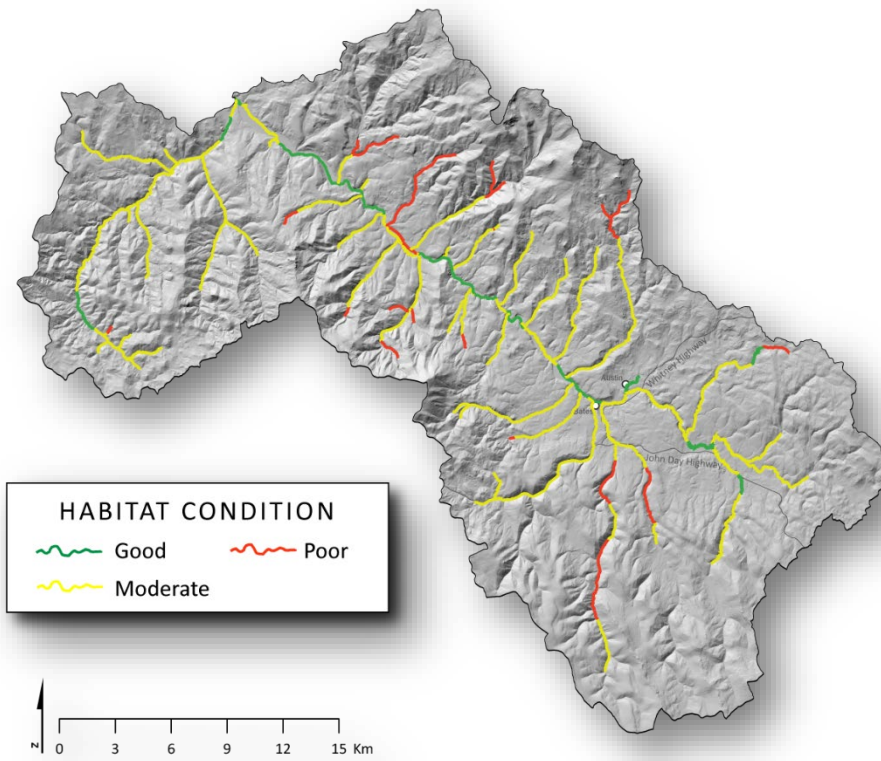
⑥ MPG/BASIN



FOR CONCEPTUAL PURPOSES ONLY
NOT FOR DISTRIBUTION

Riverscape Argument For Network Scale

‘A continuous view of the river is needed to understand how processes interacting among scales set the context for stream fishes and their habitat’ – Fausch et al. (2002)



Hierarchical Spatial Scales - Habitat

202

C. A. Frissell and others

Figure 2 Frissell et al. (2006)

DOI: [10.1007/BF01867358](https://doi.org/10.1007/BF01867358)

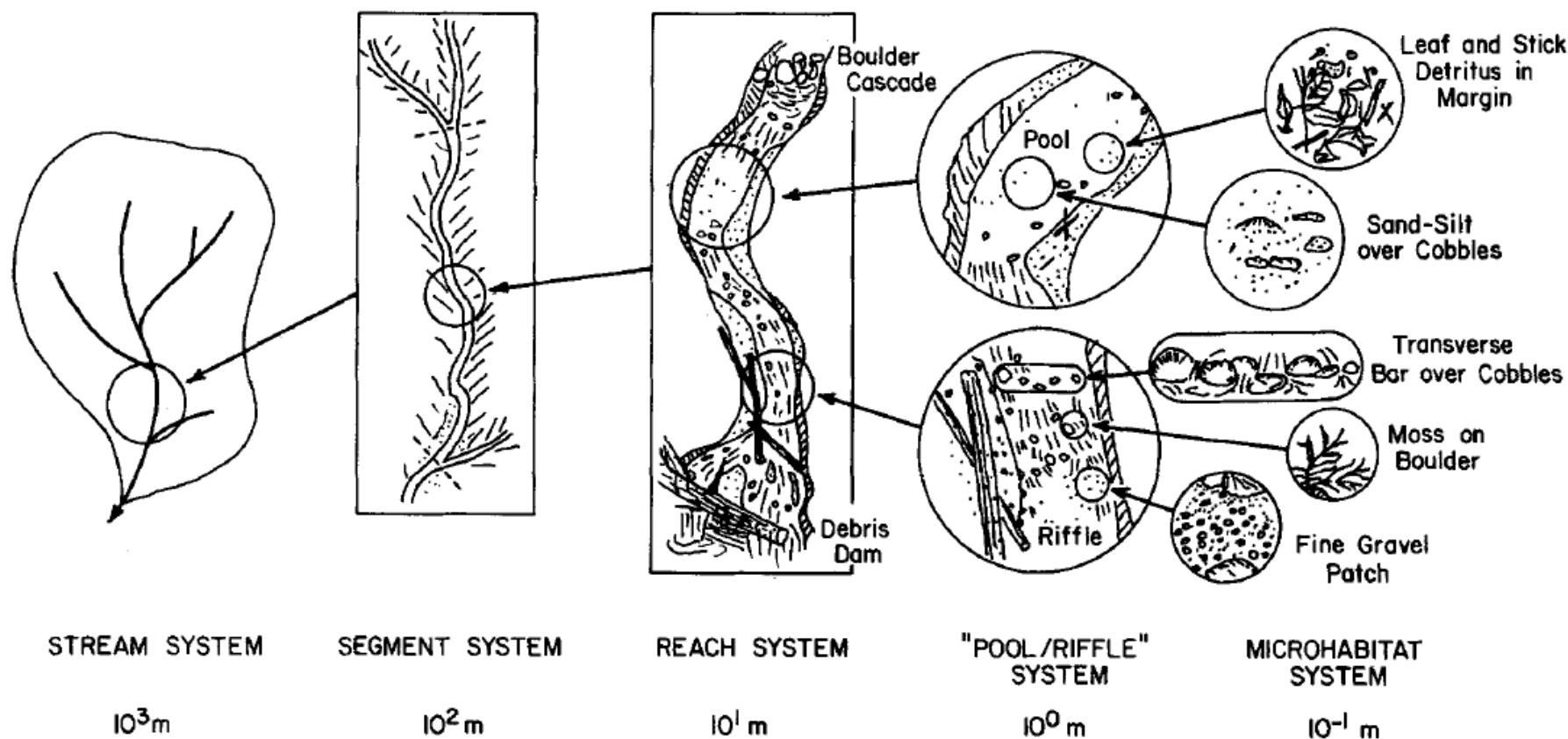
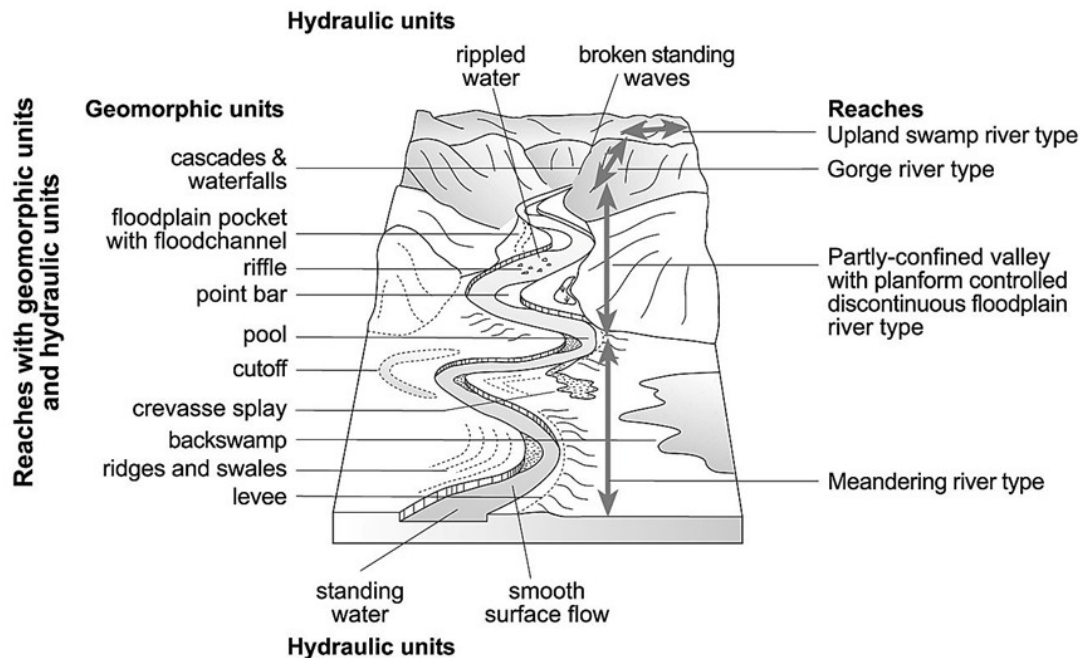
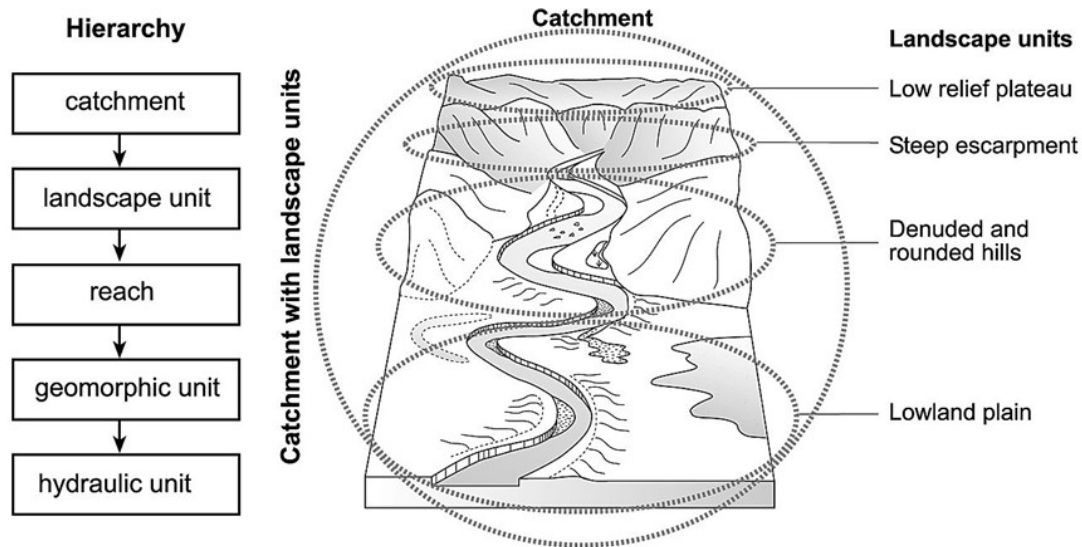


Figure 2. Hierarchical organization of a stream system and its habitat subsystems. Approximate linear spatial scale, appropriate to second- or third-order mountain stream, is indicated.



Spatial Scales of River Structure

- Reach
 - Made of many geomorphic units
- Geomorphic Unit
 - Building blocks of reach
 - Chapters 6 & 7
 - Made of multiple hydraulic units
- Hydraulic Unit
 - Area of uniform flow and substrate

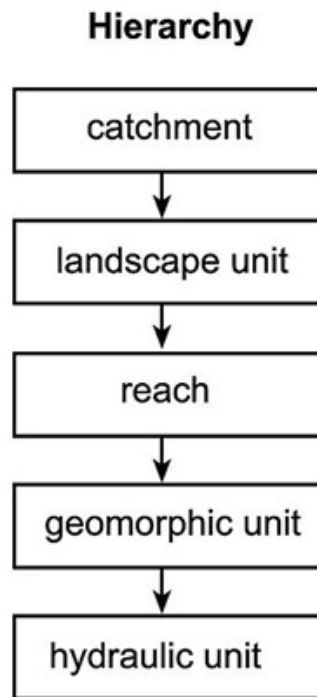
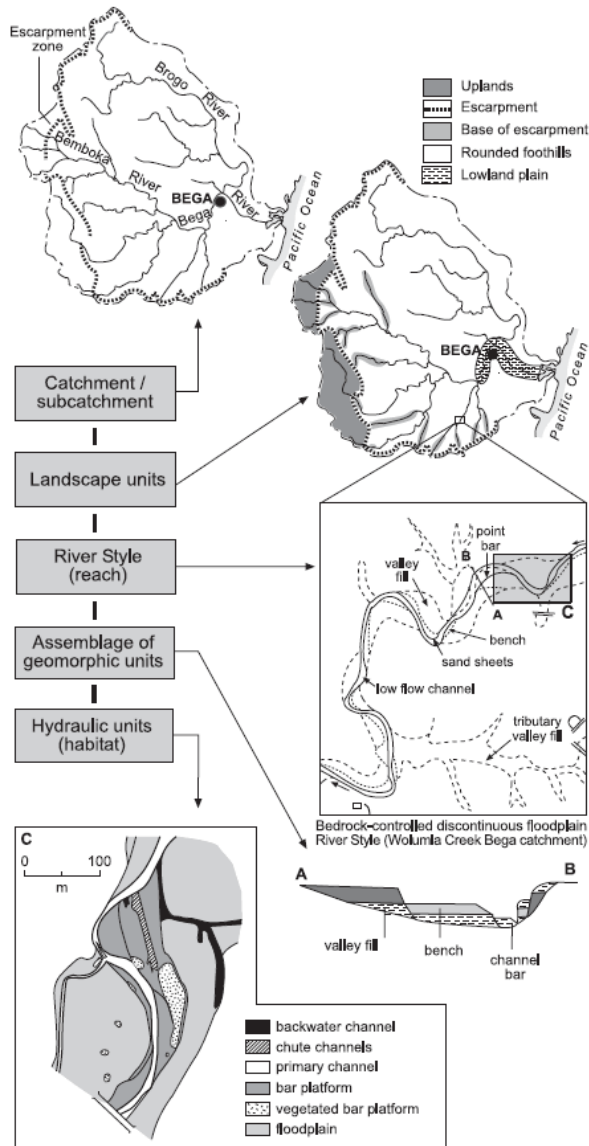


Figure 2.1 Fryirs & Brierley (2013)

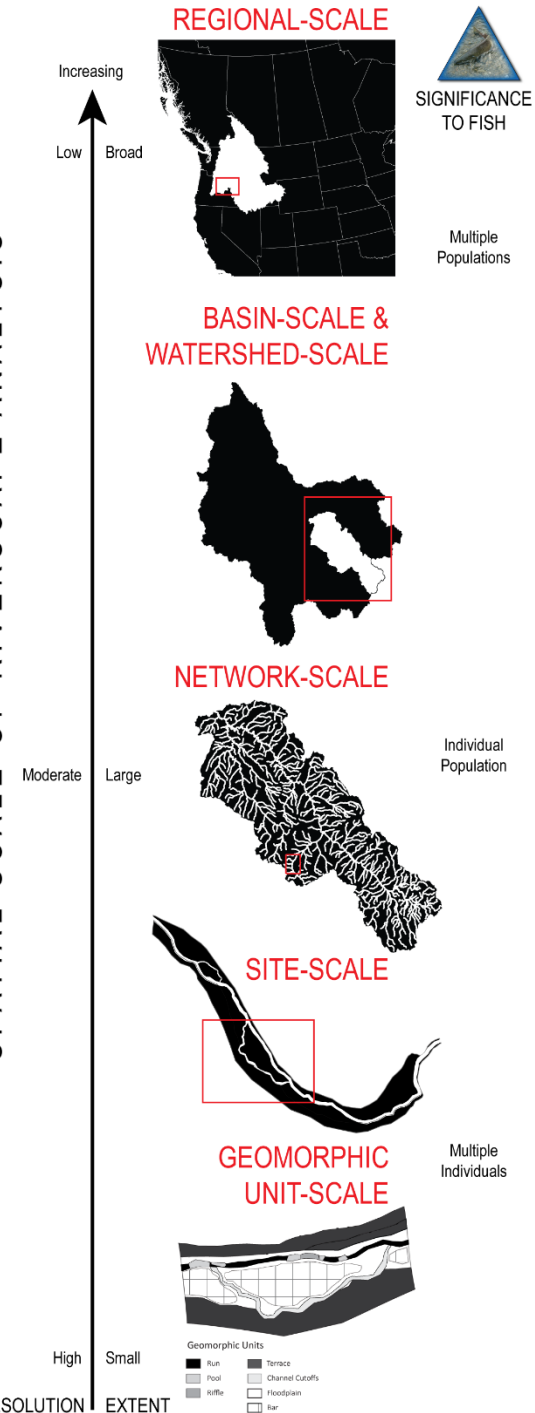
DOI: [10.1002/9781118305454](https://doi.org/10.1002/9781118305454)

All getting at same thing...

- Don't get confused by the inconsistent labels different people use.



SPATIAL SCALE OF RIVERSCAPE ANALYSIS



Boundary Conditions

Imposed

Can change over
geomorphic
timeframes

Imposed boundary conditions set by:

- (A) valley confinement and slope
- (B) base level at bedrock riffles and downstream gorges
- (C) low relief topography



- Flux boundary conditions operate within imposed boundary conditions..

Flux

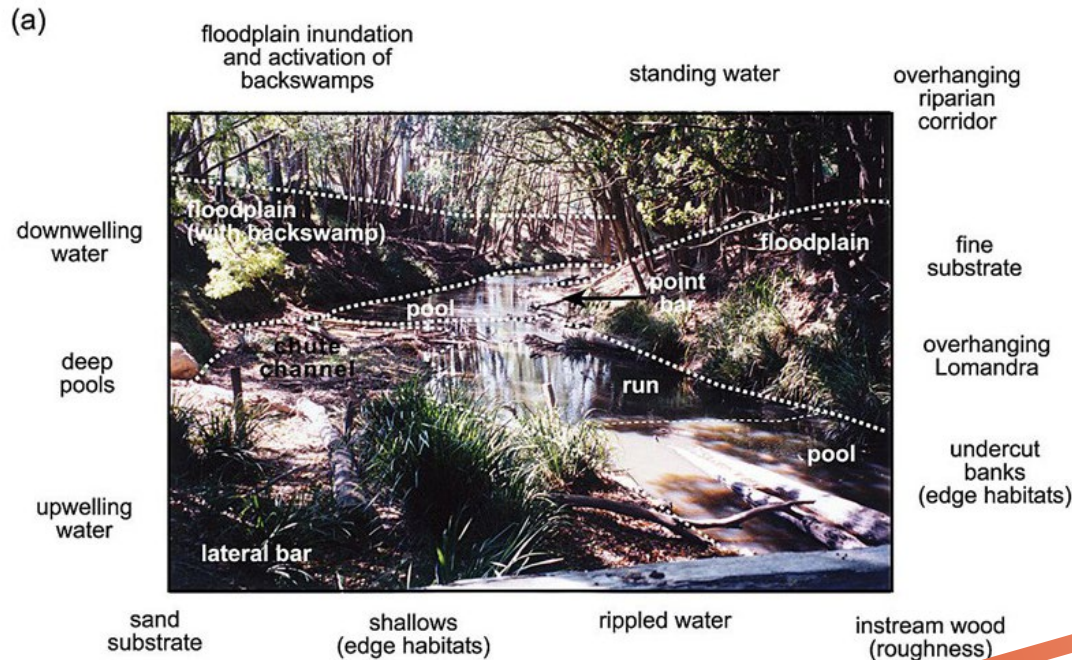
Flux boundary conditions set by interactions between water, sediment, and vegetation:

- ① flow and sediment interaction dictate zones of sediment transfer and deposition
- ② flow and sediment interaction forming different types of instream geomorphic units (e.g. bars, riffles, pools)
- ③ flow and sediment interaction forming and reworking floodplains
- ④ sediment and vegetation interaction forming different geomorphic units (e.g. ridges)
- ⑤ flow and vegetation interactions dictating variability in roughness
- ⑥ flow inundates different surfaces during discharge events of varying magnitude and frequency

Figure 2.2 Fryirs & Brierley (2013)

DOI: [10.1002/9781118305454](https://doi.org/10.1002/9781118305454)

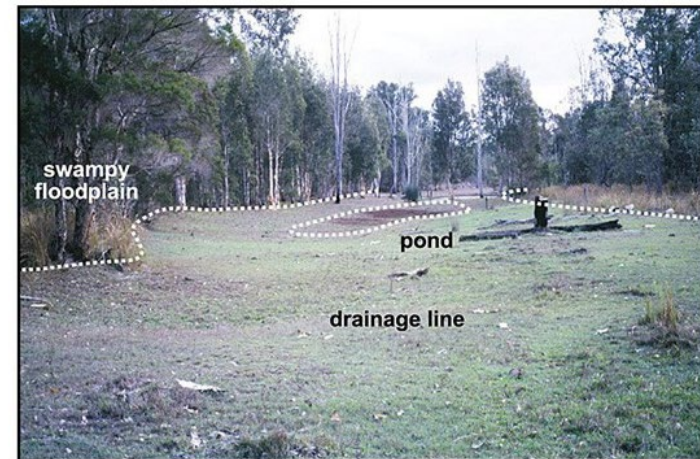
Heterogeneity and Homogeneity in Physical Structure



• something

Simple
Homogenous
Modulated Processes

Complex
Heterogenous
Amplified Processes



shallow preferential
flow

Figure 2.3 Fryirs & Brierley (2013)

DOI: [10.1002/9781118305454](https://doi.org/10.1002/9781118305454)

STRUCTURE FORCES COMPLEXITY & BUILDS RESILIENCE

RIVERSCAPES PRINCIPLE 2.

Pocket Guide; Wheaton et al. (2019, p. 5)

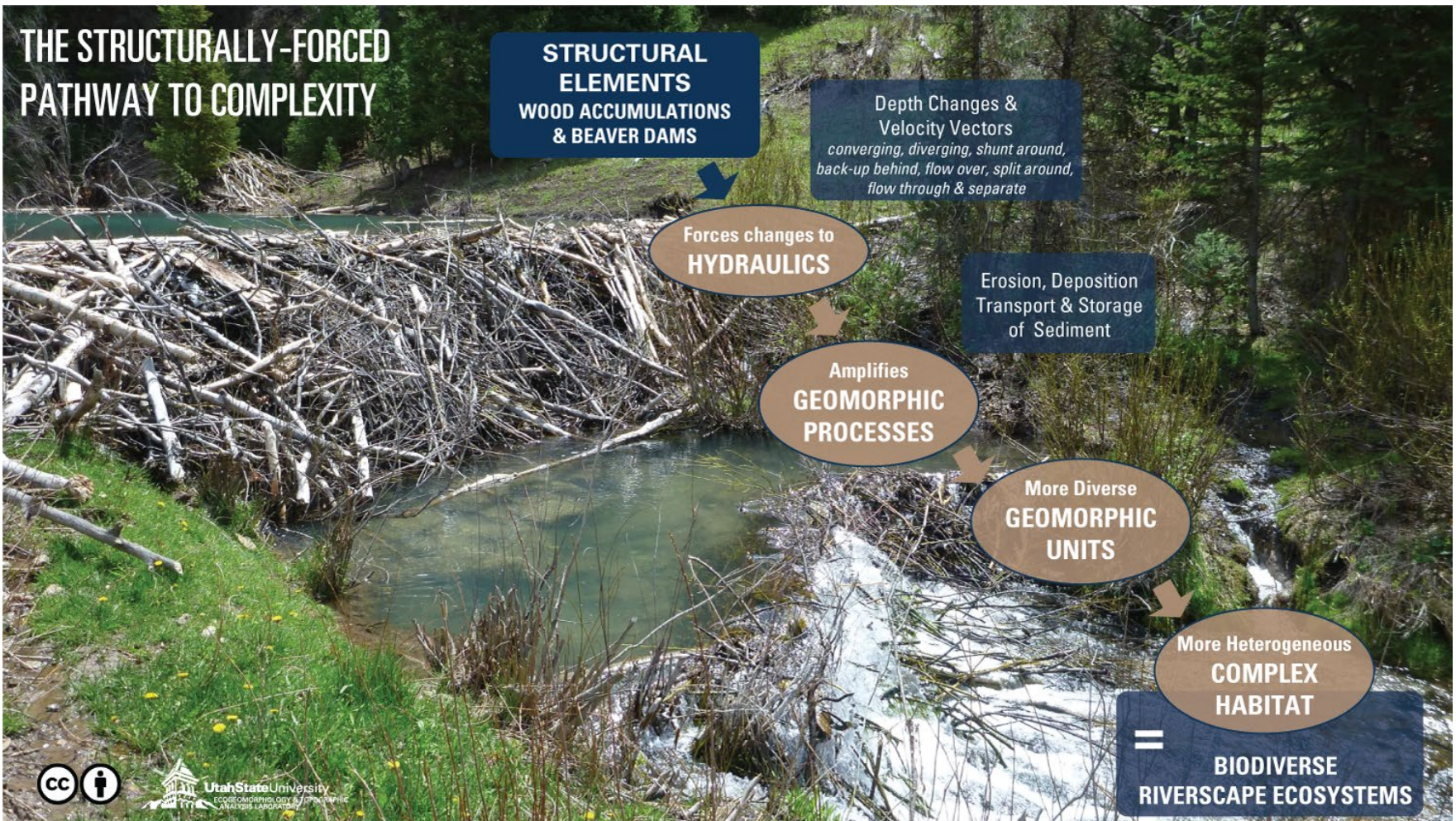
DOI: [10.13140/RG.2.2.28222.13123/1](https://doi.org/10.13140/RG.2.2.28222.13123/1)

See Wheaton et al. (2019, p 64)

Chapter 2 LTPBR Manual for Principles

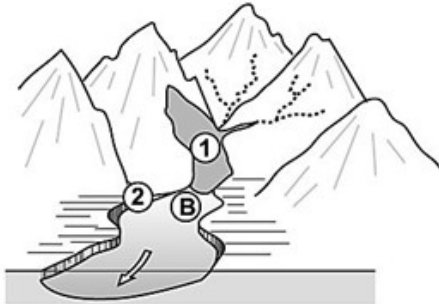
DOI: [10.13140/RG.2.2.34270.69447](https://doi.org/10.13140/RG.2.2.34270.69447)

Structural elements such as beaver dams and large woody debris force changes in flow patterns that produce physically diverse habitats. Physically diverse habitats are more resilient to disturbances than simplified, homogeneous habitats.



Typical linkages

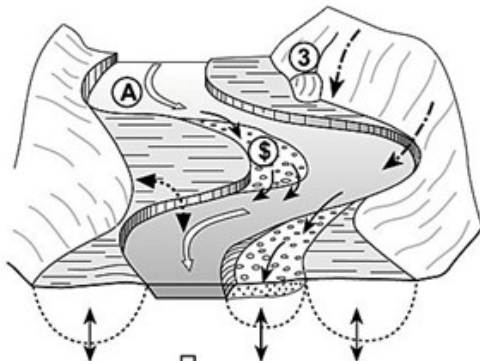
Headwaters



- Source zone
- Hillslopes and channels coupled
- Tributaries and trunk stream connected
- Efficient flow and longitudinal sediment transfer
- Limited vertical connectivity



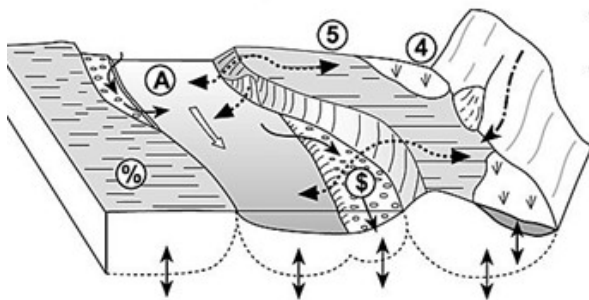
Mid - catchment



- Transfer zone
- Irregular hillslope - channel connectivity
- Tributaries may be trapped and disconnected from the trunk stream
- Efficient flow and longitudinal sediment transfer
- Channel - floodplain connectivity is irregular
- Irregular vertical exchanges



Lowland plain



- Accumulation zone
- Hillslopes and channels decoupled
- Tributaries may be trapped or disconnected from the trunk system
- Significant sediment storage
- Inefficient longitudinal sediment transfer
- Channel-floodplain connectivity is high
- Strong vertical connectivity

Variability in Landscape Connectivity

- Lets unpack this..

It is all about this being a primary control on:

- Catchment-scale fluxes of water & sediment

- Longitudinal linkages
- Lateral linkage (channel - floodplain)
- Vertical linkages
- Lateral linkage (hillslope - channel)

Buffers (landforms that affect sediment transfer from hillslopes to the channel network)

- ① landslide
- ② tributary confluence
- ③ fan
- ④ backswamp
- ⑤ floodplain

Barriers (landforms that impede downstream conveyance of sediment within the channel network)

- A sediment slug
- B dam

Blankets (features that disrupt vertical linkages)

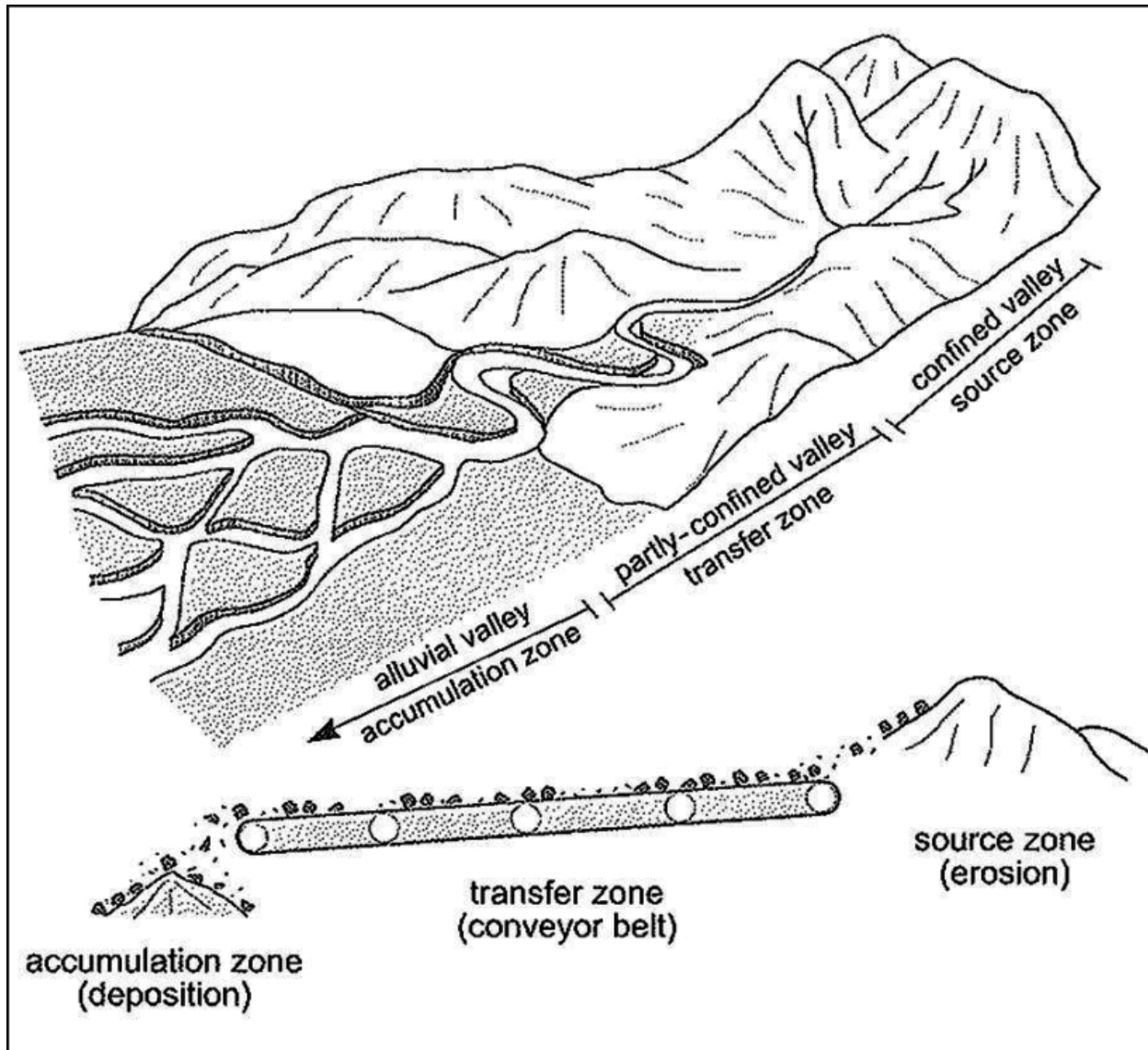
- % floodplain sand sheets
- \$ fines in interstices of gravels

Figure 2.4 Fryirs & Brierley (2013)

DOI: [10.1002/9781118305454](https://doi.org/10.1002/9781118305454)

Typical Downstream Zonation (of sediment flux)

Source → Sink

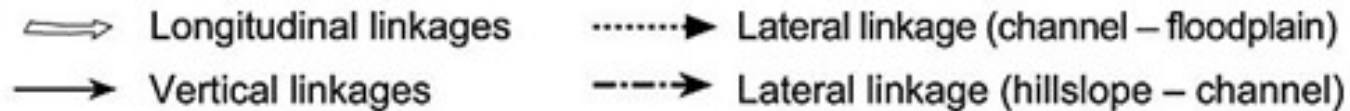


Sediment is:

- **Sourced** in *headwaters* (source zone)
- **Transferred** through *mid-catchment* (transfer zone)
- **Accumulated** in *alluvial valleys* (transfer zone) or sinks

First, the Legend is Loaded...

- Buffers – control on sediment getting to channel
- Barriers – control on sediment being conveyed downstream
- Blankets – sediment draped over surfaces



Buffers (landforms that affect sediment transfer from hillslopes to the channel network)

- ① landslide ② tributary confluence ③ fan ④ backswamp ⑤ floodplain

Barriers (landforms that impede downstream conveyance of sediment within the channel network)

- Ⓐ sediment slug Ⓑ dam

Blankets (features that disrupt vertical linkages)

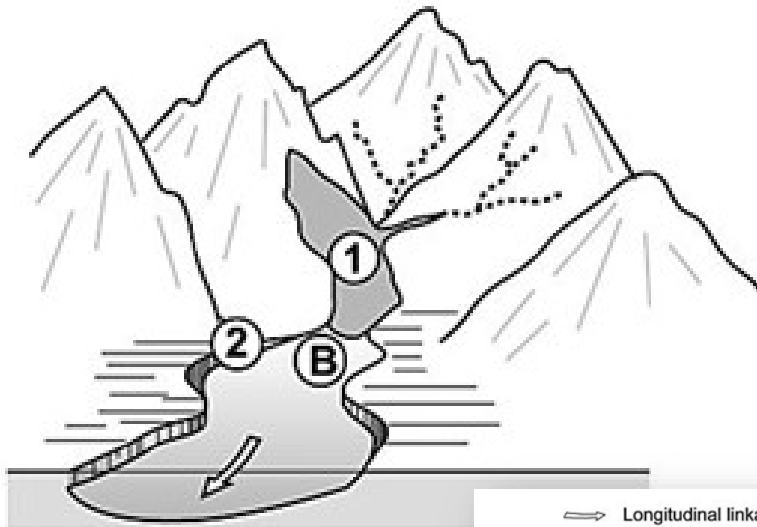
- Ⓟ floodplain sand sheets Ⓢ fines in interstices of gravels

Typical Linkages in Headwaters

- Dominated by buffers, barriers or blankets? Why?

Typical linkages

Headwaters



- Source zone
- Hillslopes and channels coupled
- Tributaries and trunk stream connected
- Efficient flow and longitudinal sediment transfer
- Limited vertical connectivity

Longitudinal linkages
 Lateral linkage (channel – floodplain)
 Vertical linkages
 Lateral linkage (hillslope – channel)

Buffers (landforms that affect sediment transfer from hillslopes to the channel network)

① landslide ② tributary confluence ③ fan ④ backswamp ⑤ floodplain

Barriers (landforms that impede downstream conveyance of sediment within the channel network)

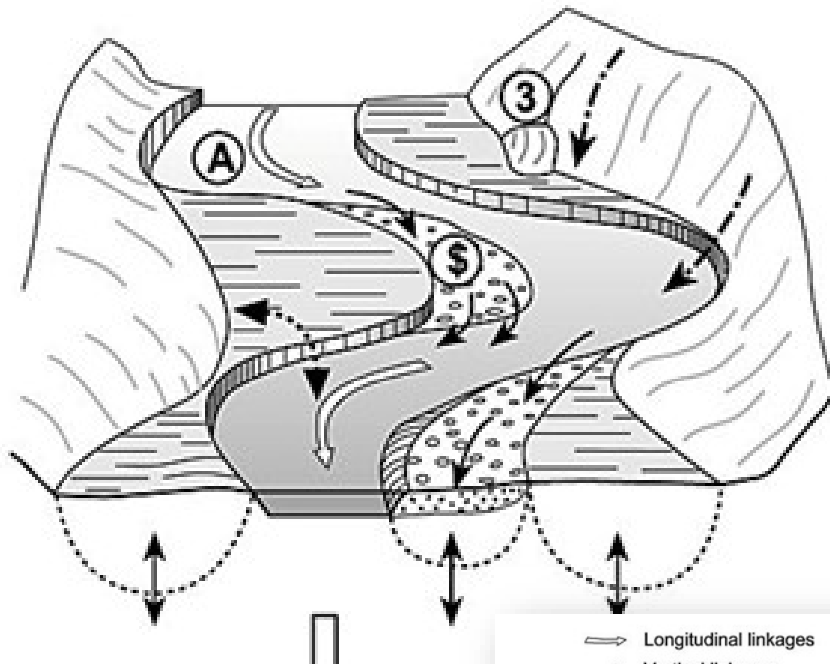
Ⓐ sediment slug Ⓑ dam

Blankets (features that disrupt vertical linkages)

Ⓟ floodplain sand sheets Ⓞ fines in interstices of gravels

Typical Linkages in Mid-Catchments

Mid - catchment



- Transfer zone
- Irregular hillslope - channel connectivity
- Tributaries may be trapped and disconnected from the trunk stream
- Efficient flow and longitudinal sediment transfer
- Channel - floodplain connectivity is irregular
- Irregular vertical exchanges

———> Longitudinal linkages > Lateral linkage (channel – floodplain)
 ———> Vertical linkages - - -> Lateral linkage (hillslope – channel)

Buffers (landforms that affect sediment transfer from hillslopes to the channel network)

① landslide ② tributary confluence ③ fan ④ backswamp ⑤ floodplain

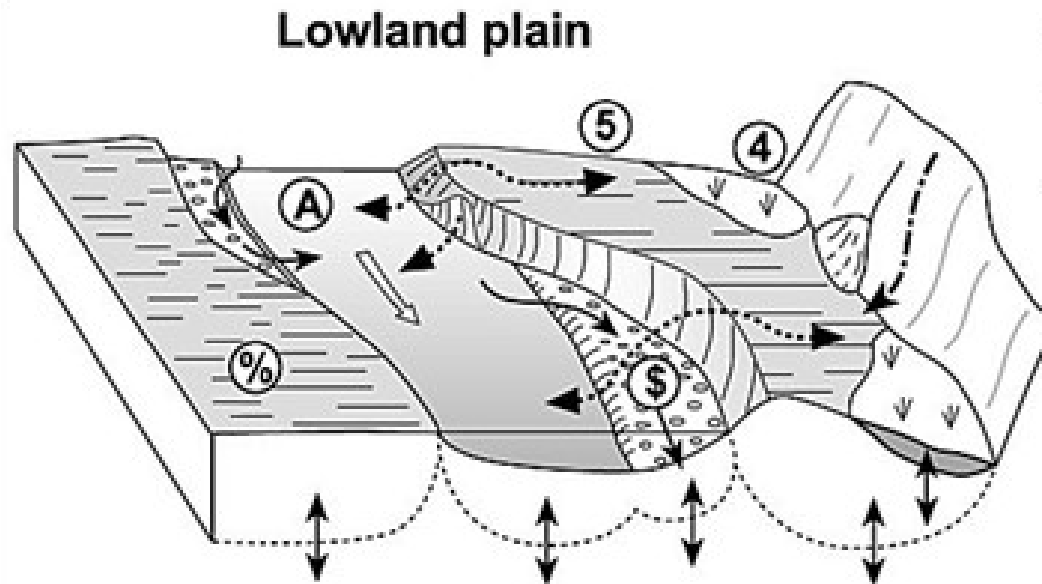
Barriers (landforms that impede downstream conveyance of sediment within the channel network)

Ⓐ sediment slug Ⓑ dam

Blankets (features that disrupt vertical linkages)

Ⓢ floodplain sand sheets Ⓣ fines in interstices of gravels

Typical Linkages in Lowland Plains



- Accumulation zone
- Hillslopes and channels decoupled
- Tributaries may be trapped or disconnected from the trunk system
- Significant sediment storage
- Inefficient longitudinal sediment transfer
- Channel-floodplain connectivity is high
- Strong vertical connectivity

⇨ Longitudinal linkages Lateral linkage (channel – floodplain)
 → Vertical linkages - - - Lateral linkage (hillslope – channel)

Buffers (landforms that affect sediment transfer from hillslopes to the channel network)

① landslide ② tributary confluence ③ fan ④ backswamp ⑤ floodplain

Barriers (landforms that impede downstream conveyance of sediment within the channel network)

Ⓐ sediment slug Ⓑ dam

Blankets (features that disrupt vertical linkages)

Ⓜ floodplain sand sheets Ⓢ fines in interstices of gravels

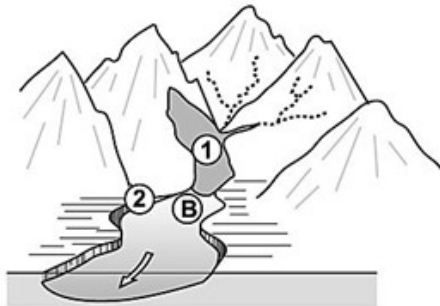
Downstream
changes in
linkages

increasing sediment storage
longer residence times of sediment stores
decreasing sediment delivery
decreasing hillslope-channel connectivity
increasing channel-floodplain connectivity

increasing sediment storage
longer residence times of sediment stores
decreasing sediment delivery
decreasing hillslope-channel connectivity
increasing channel-floodplain connectivity

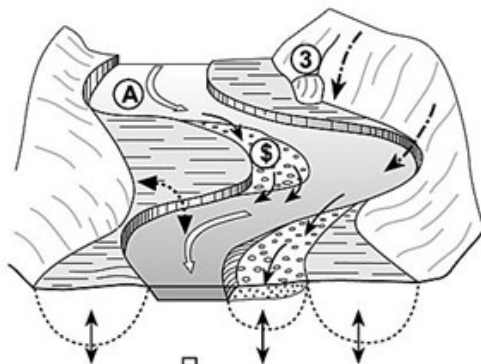
Typical linkages

Headwaters



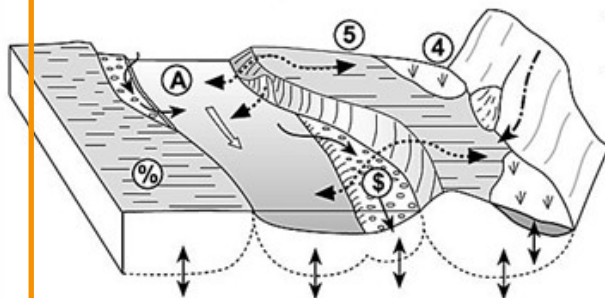
- Source zone
- Hillslopes and channels coupled
- Tributaries and trunk stream connected
- Efficient flow and longitudinal sediment transfer
- Limited vertical connectivity

Mid - catchment



- Transfer zone
- Irregular hillslope - channel connectivity
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Lowland plain



- Accumulation zone
- Hillslopes and channels decoupled
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- Significant sediment storage
- Inefficient longitudinal sediment transfer
- Channel-floodplain connectivity is high
- Strong vertical connectivity

Typical Downstream Patterns

How these linkages change downstream in:

- Sediment storage (+)
- Residence time of sediment (+)
- Sediment delivery (-)
- Hillslope-Channel Connectivity (-)
- Channel-Floodplain Connectivity (+)

Longitudinal linkages
Lateral linkage (channel - floodplain)
Vertical linkages
Lateral linkage (hillslope - channel)

Buffers (landforms that affect sediment transfer from hillslopes to the channel network)

① landslide ② tributary confluence ③ fan ④ backswamp ⑤ floodplain

Barriers (landforms that impede downstream conveyance of sediment within the channel network)

A sediment slug B dam

Blankets (features that disrupt vertical linkages)

% floodplain sand sheets \$ fines in interstices of gravels

Figure 2.4 Fryirs & Brierley (2013)

DOI: [10.1002/9781118305454](https://doi.org/10.1002/9781118305454)

Key Concepts in Fluvial Geomorphology

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III. Conceptualization of Time

IV. Combining Spatial & Temporal Concepts



Timeframes of River Analysis

- Temporal scale is defined in terms of duration (frame) and frequency
- We'll start with Geologic Time...

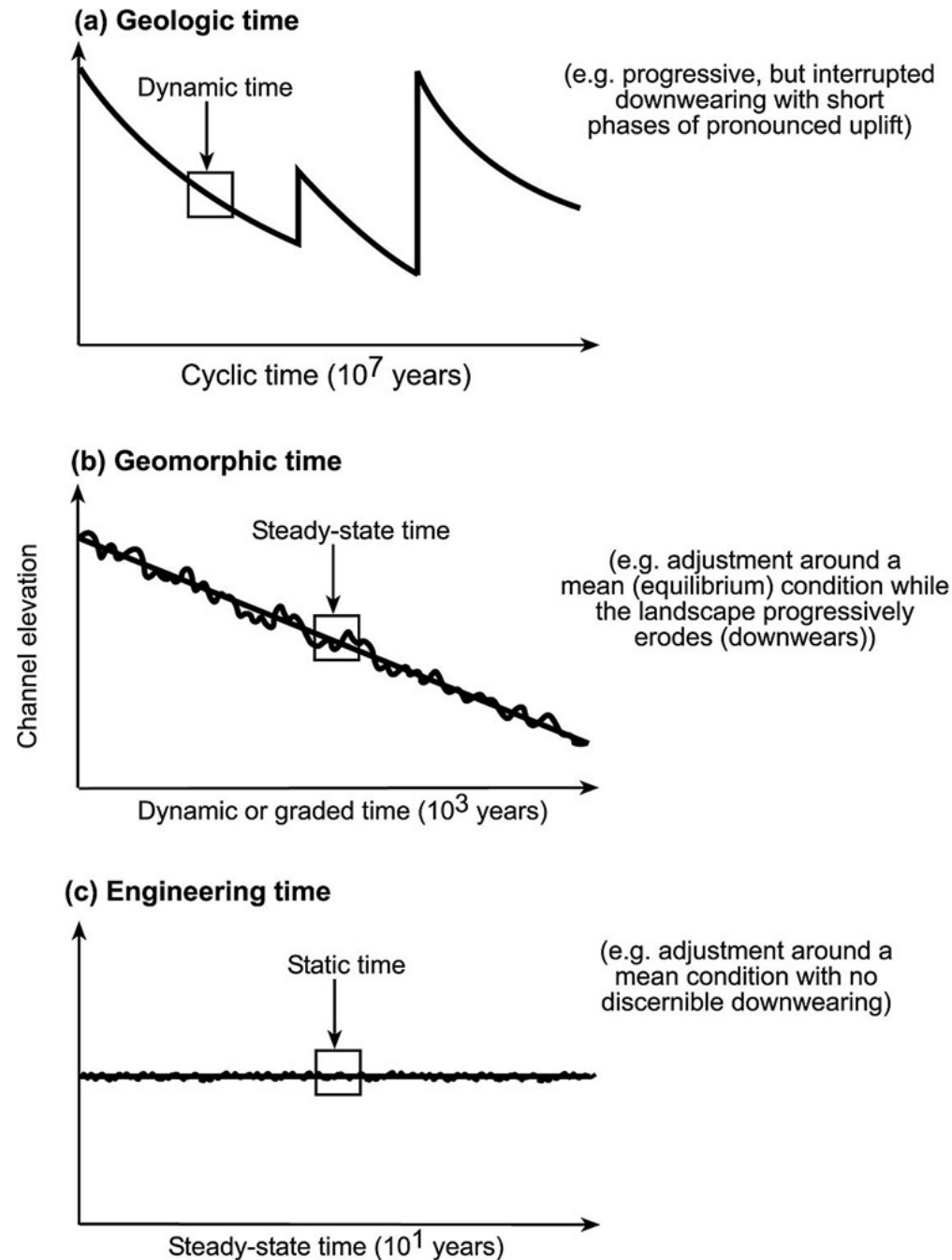


Figure 2.5 Fryirs & Brierley (2013)

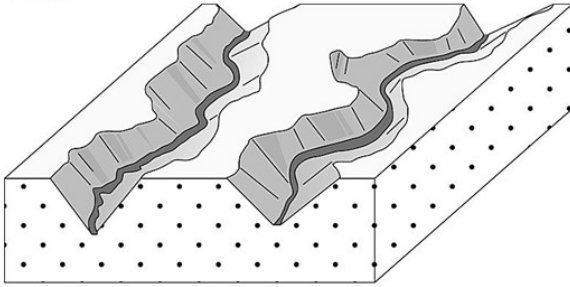
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Daviesian Cycle of Landscape Erosion

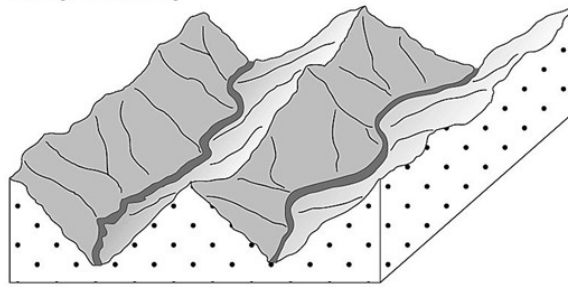


Three Stages
Spanning
'Geologic Time'

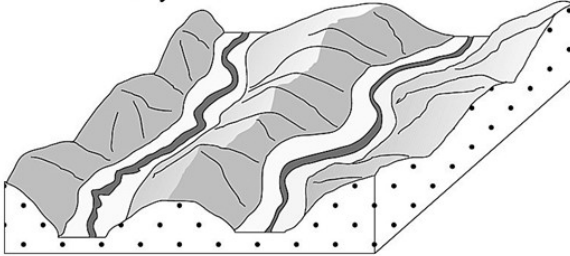
Youth



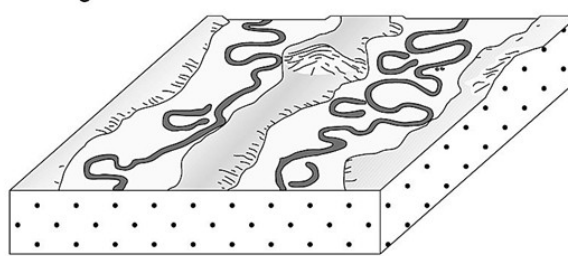
Early Maturity



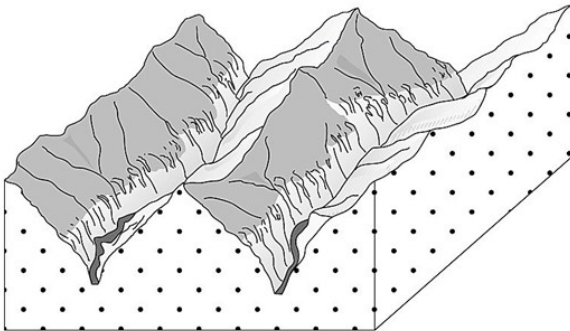
Late Maturity



Old Age



Rejuvenation of an Early Maturity landscape



Rejuvenation of an Old Age landscape

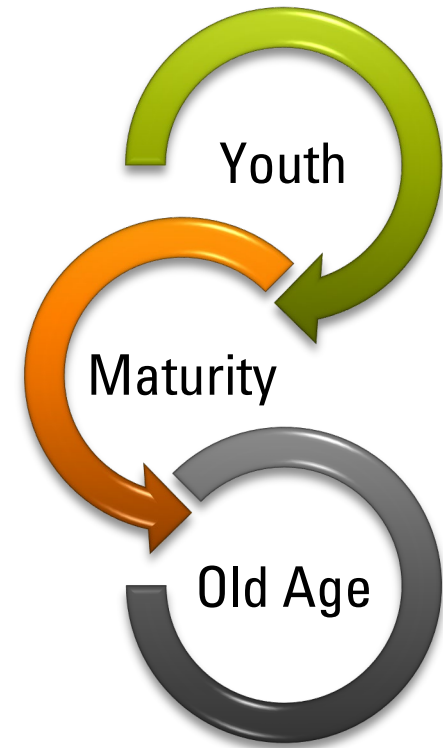
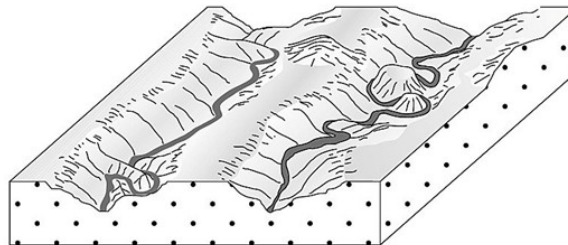
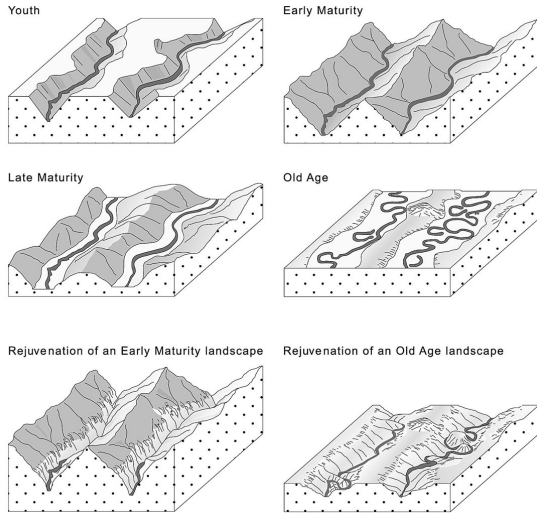


Figure 2.6 Fryirs & Brierley (2013)

DOI: [10.1002/9781118305454](https://doi.org/10.1002/9781118305454)

Daviesian Cycle of Landscape Erosion



- This is a classic example of **space for time substitution**.
- This was developed in mid 1800s, more than a century prior to concept of plate tectonics

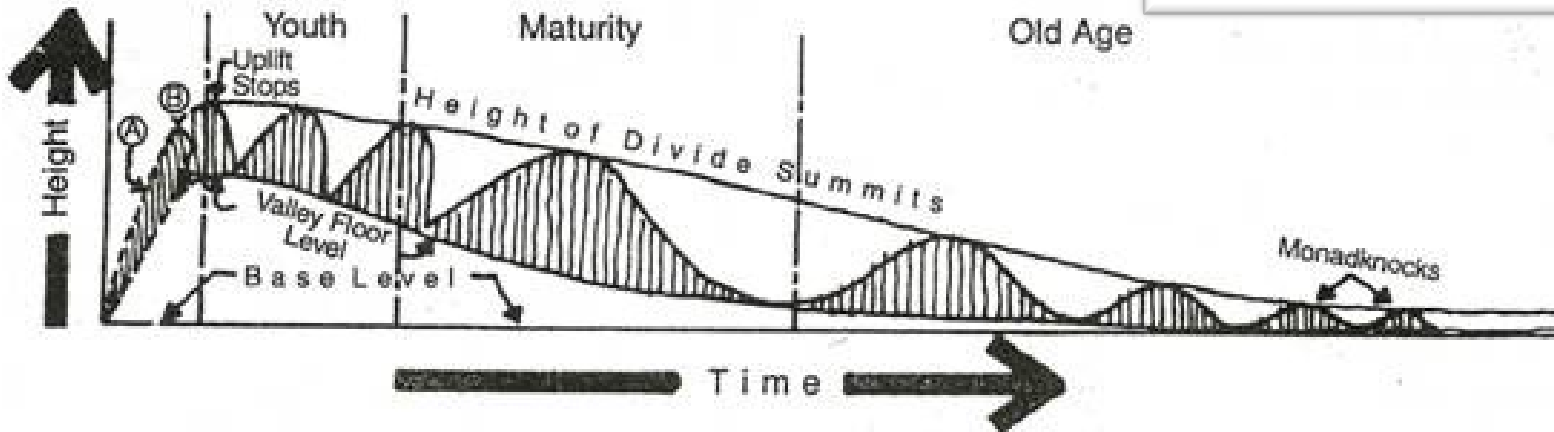
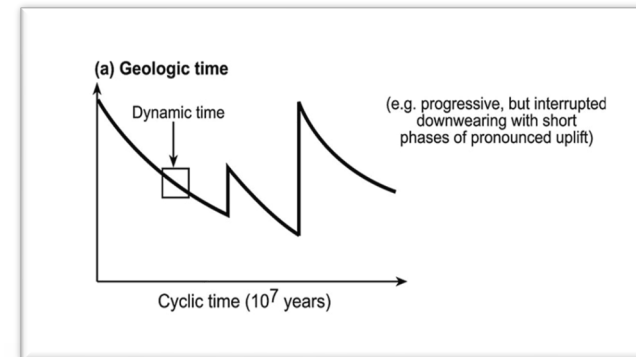


Fig. 1.44 A graphical presentation of geographical cycle proposed by W.M. Davis.

Timescales & Perspectives

- Time the geologist cares about, vs. the geomorphologist, vs. the engineer

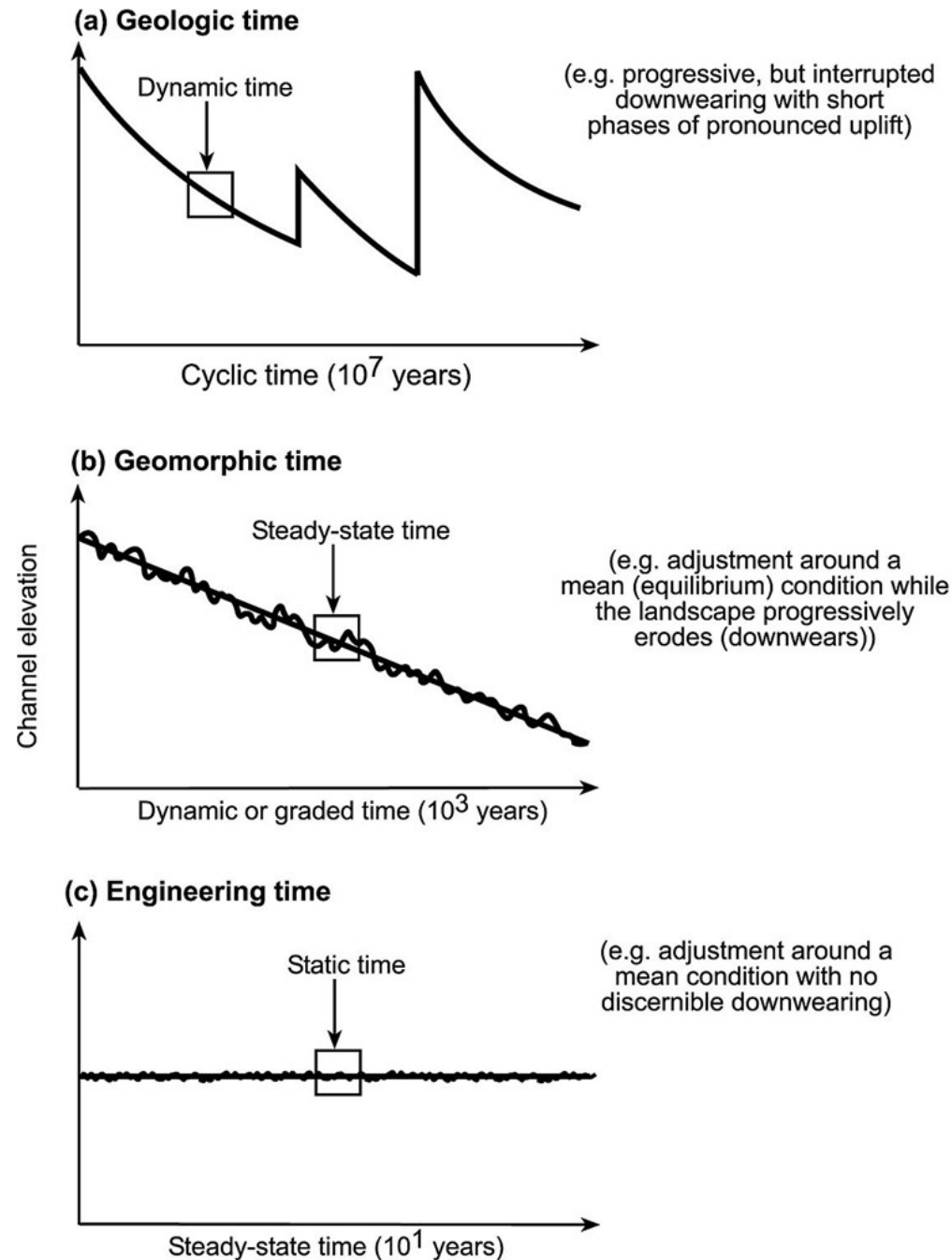


Figure 2.5 Fryirs & Brierley (2013)

DOI: [10.1002/9781118305454](https://doi.org/10.1002/9781118305454)

Equilibrium “Notions”

- An over tendency to assume equilibrium exists and is “natural”
- Equilibrium cannot be defined without being explicit about timescale
- Equilibrium of what? What variable? Elevation, Sediment Flux, Channel State, etc?

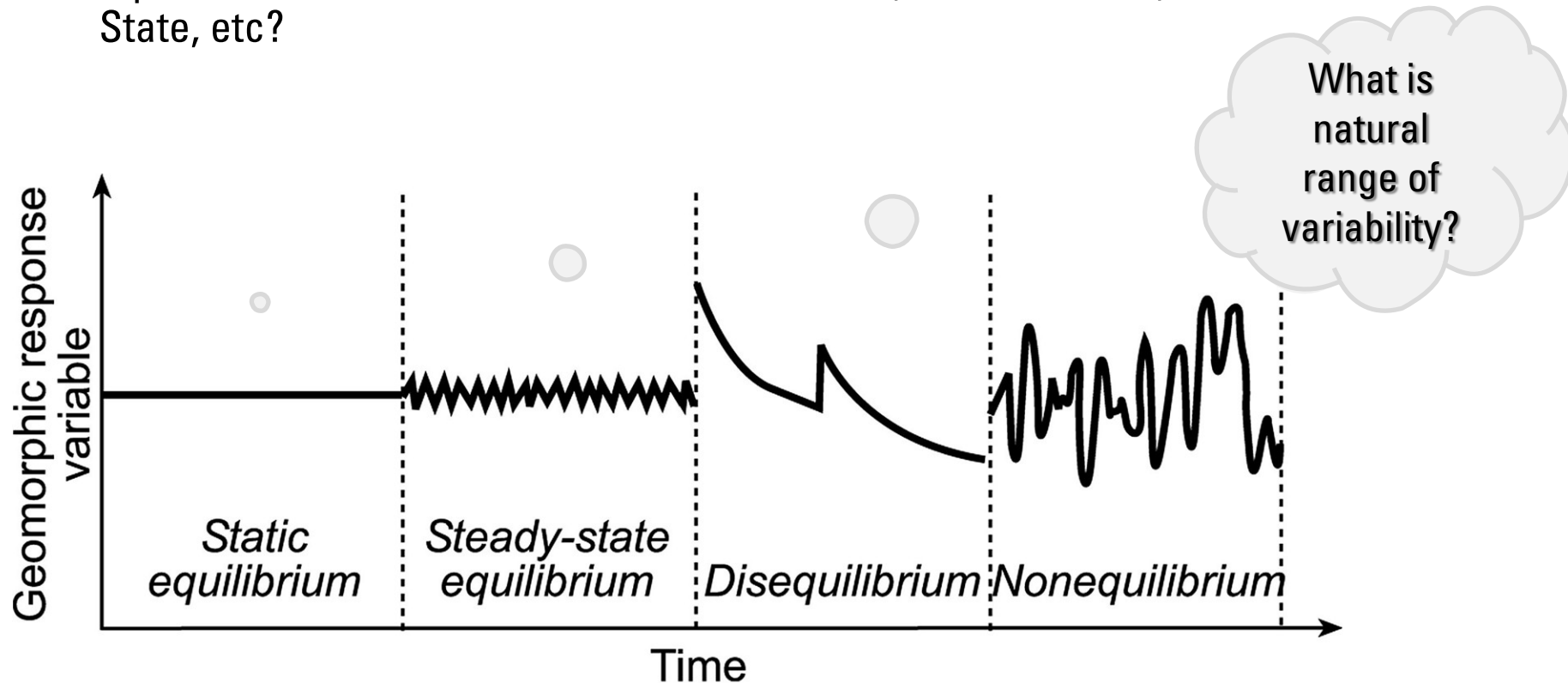
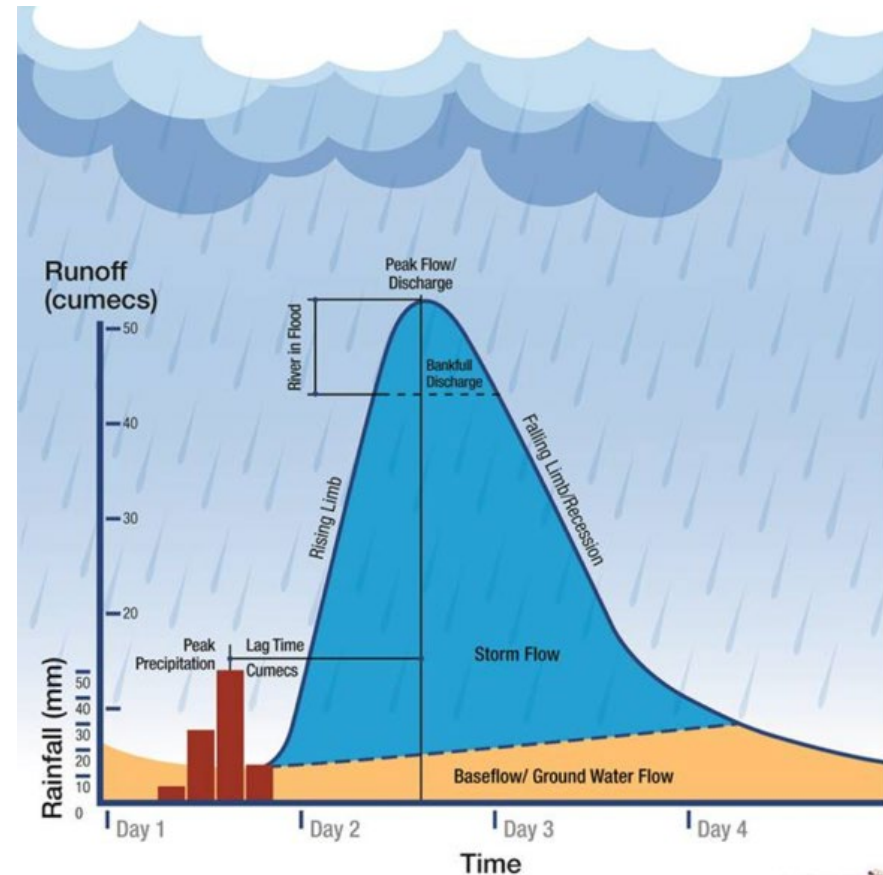


Figure Fryirs & Brierley (2013)

DOI: [10.1002/9781118305454](https://doi.org/10.1002/9781118305454)

Disturbance Events

- A change in process intensity – any factor that affects the boundary conditions
- *Pulse Events* – disturbance events are episodic events of low frequency, high magnitude and limited duration (e.g. seasonal flood, storm event)
- *Press Events* - Controlling variables are sustained at a new level as a result of more permanent shifts in input/flux conditions (e.g. flow regulation)
- *Ramp Events* – Strength of disturbance steadily increases over time and space (e.g. land use changes)



Geomorphic “Effectiveness” of Floods

- Not a hydrograph
- The biggest events are not always the most “effective”
- The longest events are not always the most effective

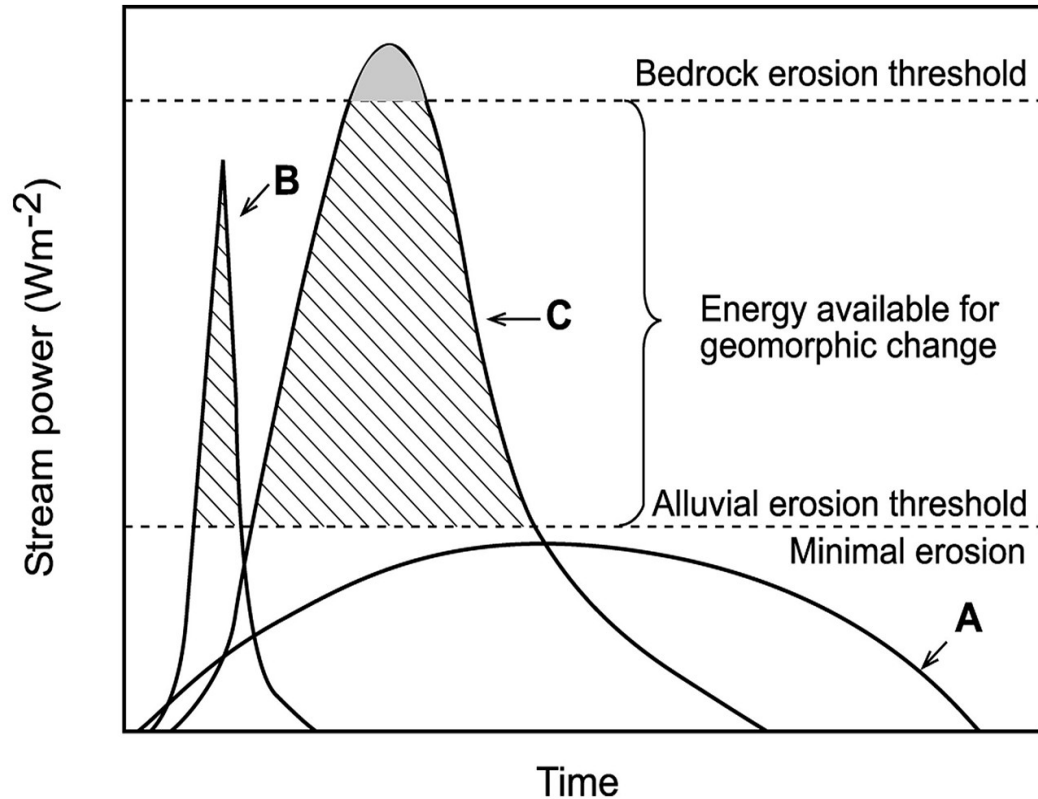


Figure 2.11 A conceptual approach to analysis of the geomorphic effectiveness of floods. Flood C is the most geomorphically effective flood because the energy available to do work is high, the duration of the event long and the thresholds of alluvial and bedrock erosion exceeded. Flood B is less effective as it has short duration beyond the alluvial threshold, and is unable to rework bedrock. Flood A does not extend beyond the alluvial threshold, so it is geomorphically ineffective. Modified from Costa and O'Connor (1995). © American Geophysical Union. Reproduced with permission.

Flood	Magnitude above threshold	Event Duration	“Effectiveness”
A	None	Longest	Least (not)
B	Some	Shortest	Medium
C	Most	Intermediate	Most

Figure 2.11 Fryirs & Brierley (2013)

DOI: [10.1002/9781118305454](https://doi.org/10.1002/9781118305454)

Concept Really Comes from Wolman & Miller's Effective Discharge

- $f(Q)$ is a frequency distribution of events
- $S(Q)$ is a rating curve – e.g. *how much sediment moved as function of flow*
- Product of two is “effectiveness”
- Take away is intermediate magnitude and frequency events “most effective”

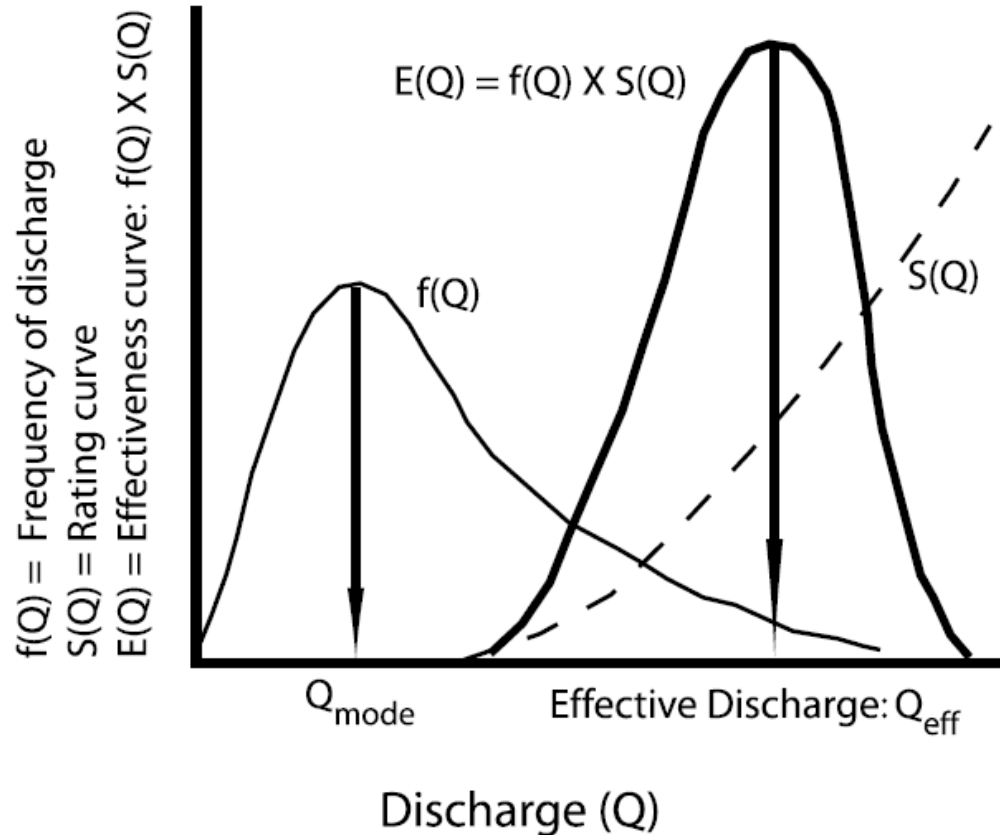


Figure 1. Components of effective discharge (Q_{eff}). Adapted from *Wolman and Miller* [1960].

However, different shape frequency & rating curves... would change that

W11411

DOYLE ET AL.: ECOLOGICAL EFFECTIVE DISCHARGE

W114

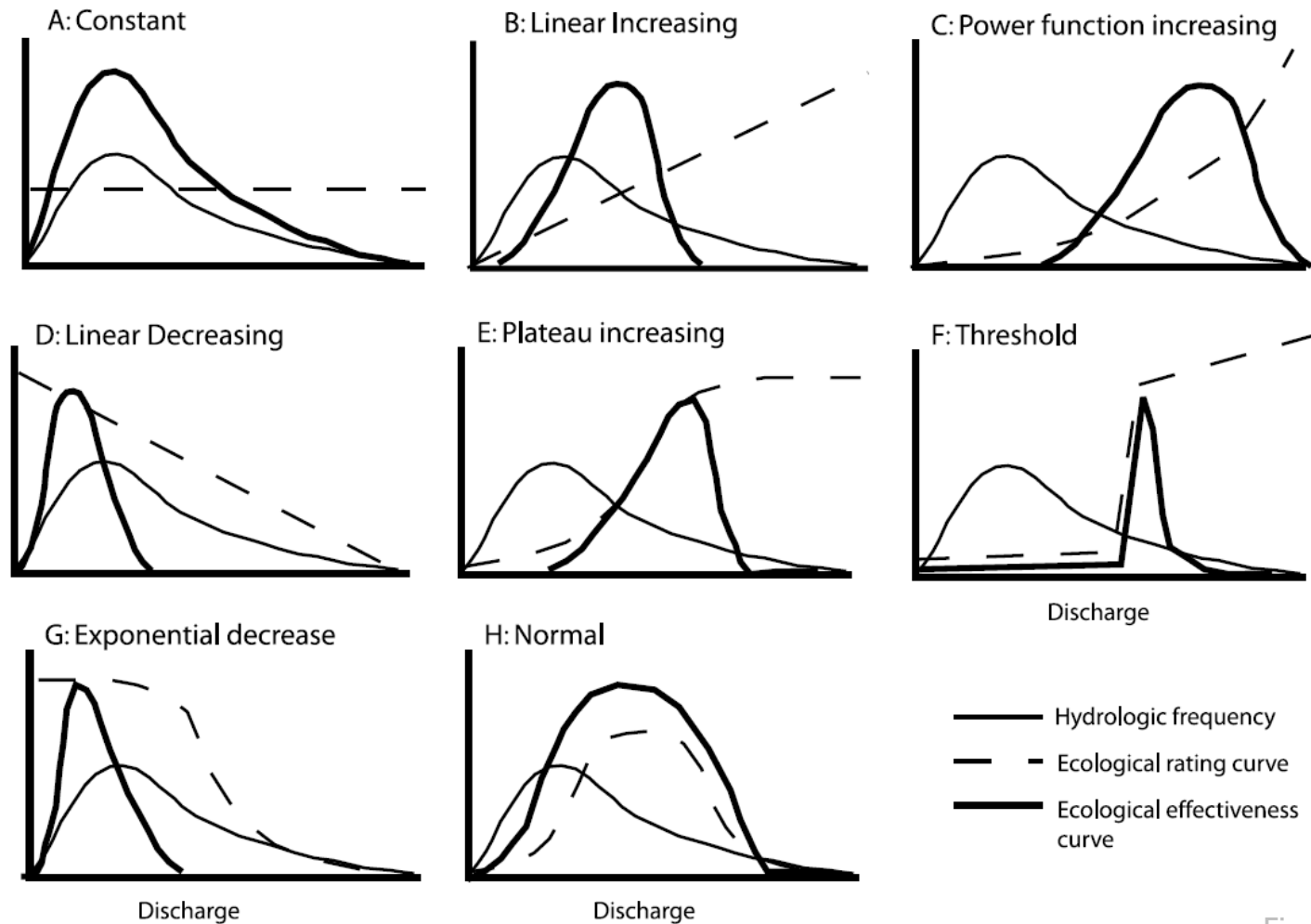


Figure 13. Hypothetical response curves for a variety of ecological variables. For potential ecological variables, see Table 2 and discussion in text.

Figure 1 Doyle et al
(2006)

DOI: [10.1029/2005wr004222](https://doi.org/10.1029/2005wr004222)

Some other *italic* Concepts



Magnitude Frequency Relationships

- *Geomorphic Work*
- *Complex Response*
- *Geomorphic Effectiveness*
- *Persistence*
- *Gradualism*
- *Catastrophism*
- *Antecedent Controls*
- *Memory*
- *Residence Time*
- *Equifinality*

Differentiating Behavior from Change

River behaviour refers to 'natural' adjustments that occur for a particular river type (e.g. lateral migration for meandering sand bed rivers).



- **Processes**... going about their normal business (i.e. adjustments around a characteristic state)

- **Different Flavor** ... boundary conditions different

River change occurs when a wholesale change in river type occurs (e.g. from an intact valley fill to a channelised fill)

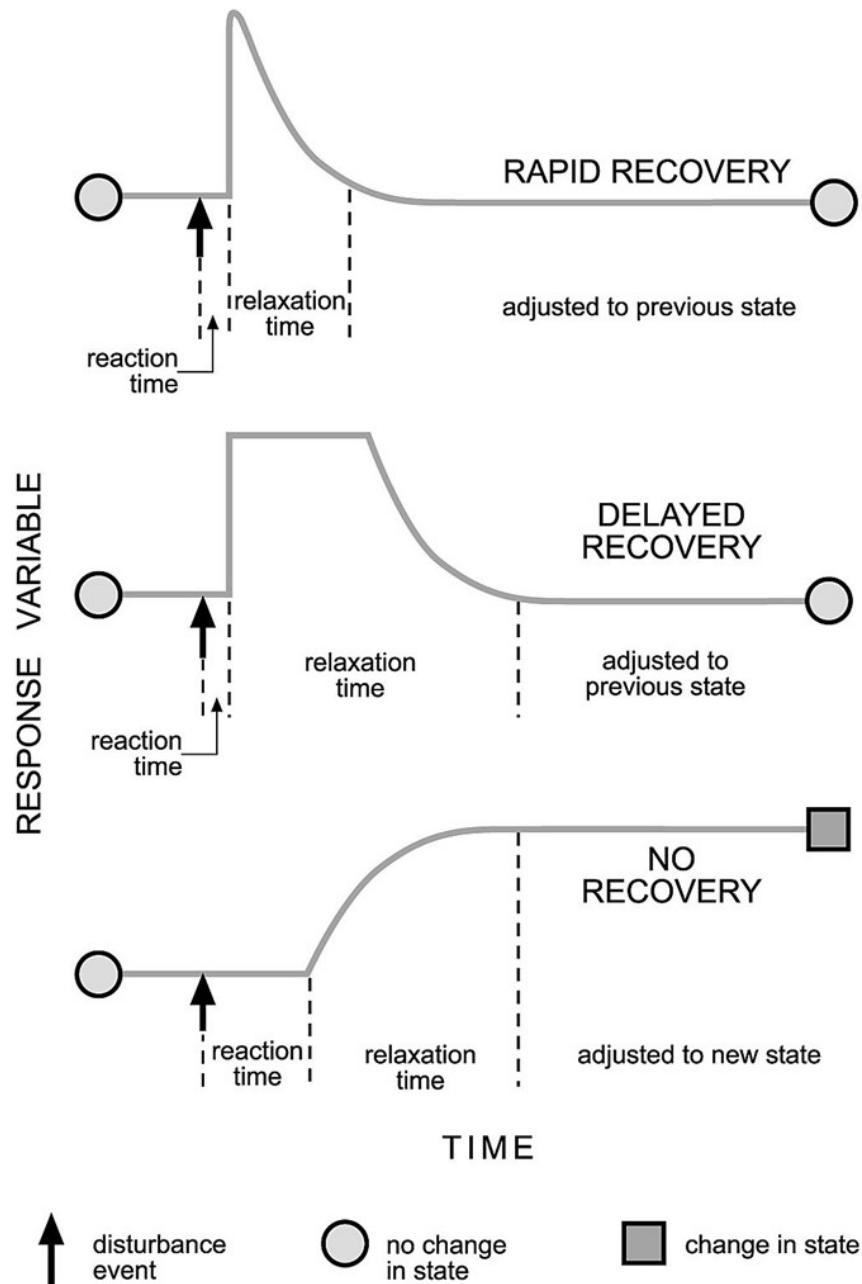
Figure 2.8 Fryirs & Brierley (2013)

DOI: [10.1002/9781118305454](https://doi.org/10.1002/9781118305454)



Time – Response Plots

Key Concepts



- Disturbance Events
- Thresholds
- Reaction Time
- Relaxation Time
- Recovery

Figure Fryirs & Brierley (2013)

DOI: [10.1002/9781118305454](https://doi.org/10.1002/9781118305454)

So when river behavior just taking place...

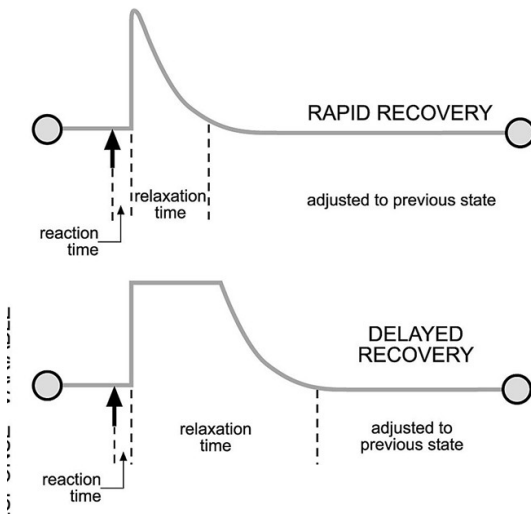
River behaviour refers to 'natural' adjustments that occur for a particular river type (e.g. lateral migration for meandering sand bed rivers).



- **Processes...** going about their normal business (i.e. adjustments around a characteristic state)

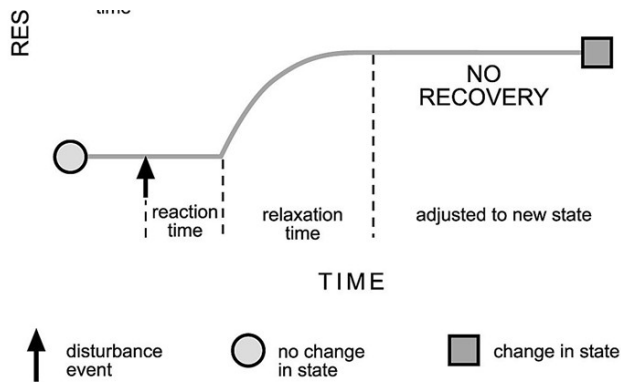
Figure 2.8 Fryirs & Brierley (2013)

DOI: [10.1002/9781118305454](https://doi.org/10.1002/9781118305454)



- If a big disturbance event happens... **System Recovers** ... May be rapid or delayed

However, Flavor Change can Occur when



- If a big disturbance event happens... and **System Does Not Recover** ... some

- **Different Flavor ...**
boundary conditions
different

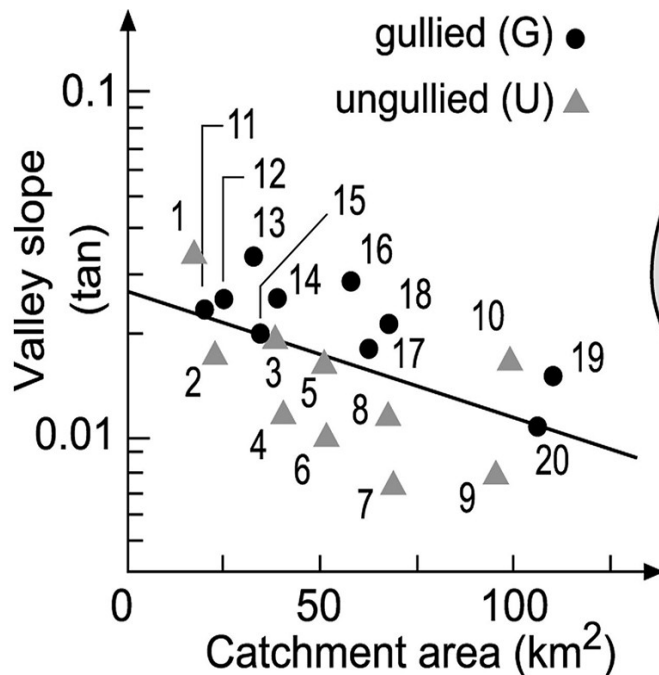
Figure 2.8 Fryirs & Brierley (2013)

DOI: [10.1002/9781118305454](https://doi.org/10.1002/9781118305454)

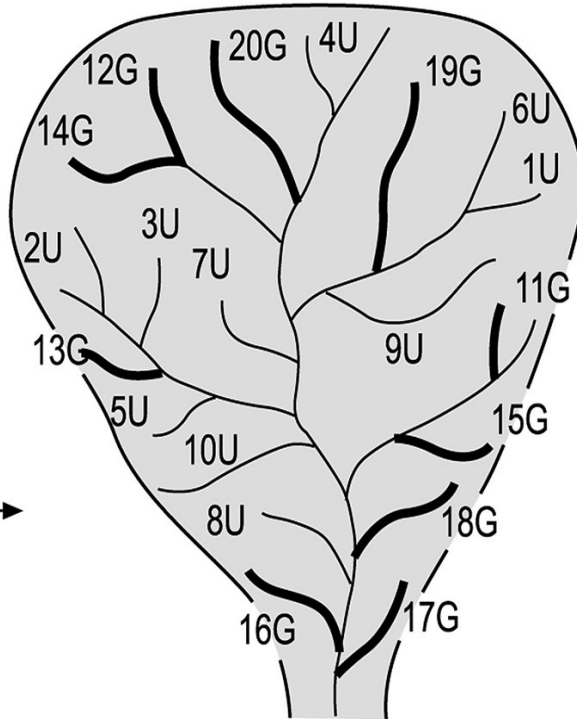
River change occurs when a wholesale change in river type occurs (e.g. from an intact valley fill to a channelised fill)



Thresholds define transitions in geomorphic state



1 & 10 = Highly sensitive
3 & 5 = Sensitive
7 = Least sensitive



What is the
inverse of
sensitivity?

- When a threshold is exceeded, the “state” changes
- When a system is near a threshold, but it hasn’t changed state, it is sensitive

Figure 2.9 Thresholds define transitions in geomorphic state. In this example, unincised valley floors generally lie below the discriminating function line with low slopes for a given catchment area, while incised valley floors generally lie above the discriminating (slope–catchment area) function. Disturbance events are likely to exceed threshold conditions, thereby inducing gully erosion for sites 1 and 10 while sites 3 and 5 are also prone to incision given their closeness to the threshold (modified from Patton and Schumm (1975)).

Figure Fryirs & Brierley (2013)

DOI: [10.1002/9781118305454](https://doi.org/10.1002/9781118305454)

Resilience of _____, (*some system state*) to _____ (*some disturbance*)

What is resilience?

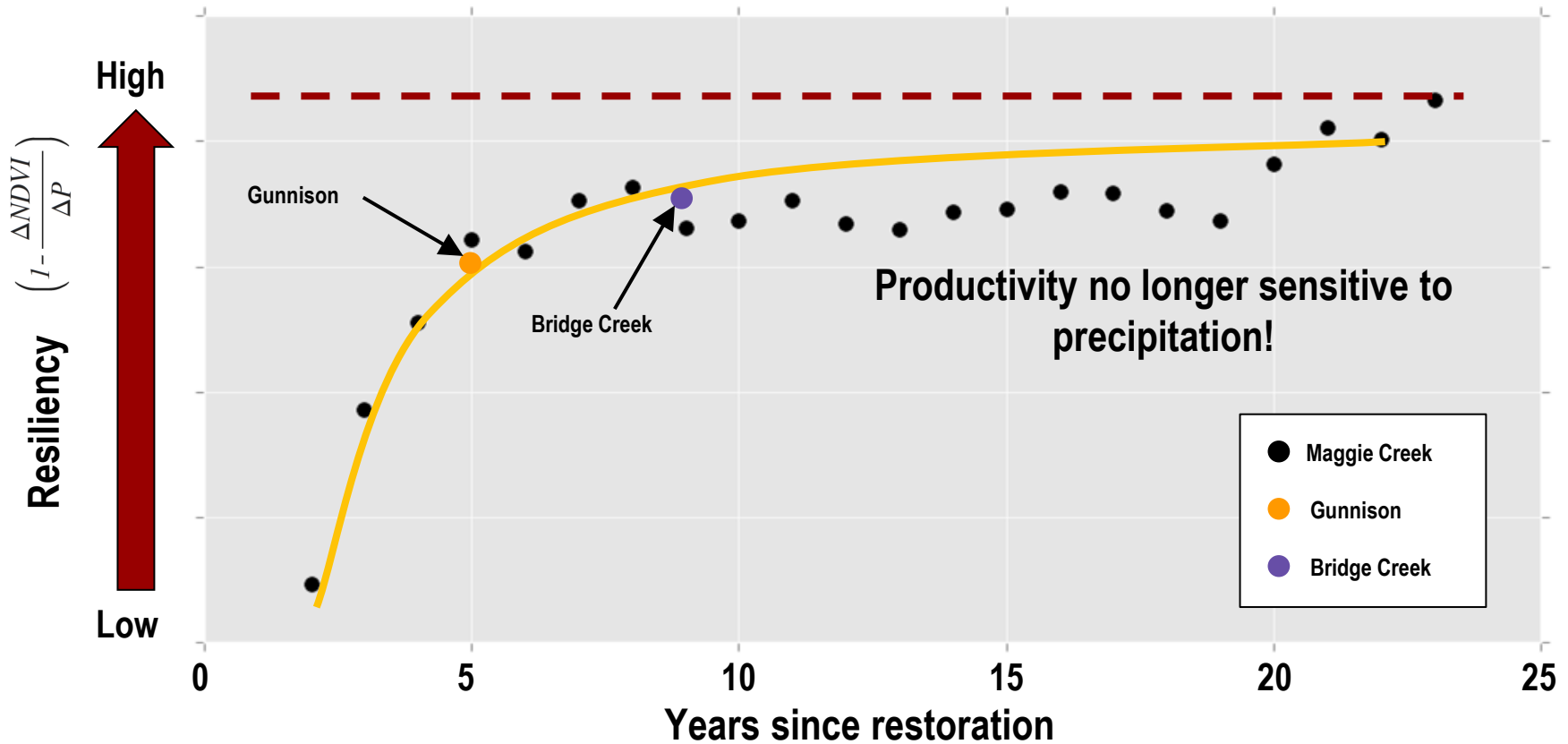
"The capacity to recover quickly from difficulties, toughness."

The lack of sensitivity to disturbance



Structurally-Forced Resilience to Drought

Silverman et al. (2018)
DOI: <https://doi.org/10.1111/rec.12869>
Page 15 of LTPBR Pocket Guide



Zeedyk Structures

(Short-term: 2-5 yrs)



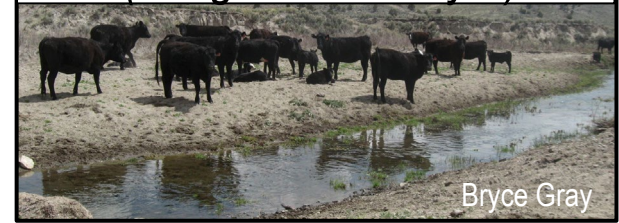
Beaver Dam Analogs

(Mid-term: 9 yrs)



Grazing Management

(Long-term: 20+ yrs)



Another example of Structurally-Forced Resilience

Riparian areas burnt to ground across entire valley bottom in most the watershed

EXCEPT, where beaver dam complexes kept the valley bottoms wet, the riparian areas did not burn!

Page 16 of LTPBR Pocket Guide
From Wheaton et al. (2019) – LTPBR Manual

DOI: [10.13140/RG.2.2.19590.63049/1](https://doi.org/10.13140/RG.2.2.19590.63049/1)

Key Concepts in Fluvial Geomorphology

- I. Intro
- II. Spatial Considerations
- III. Conceptualization of Time
- IV. Combining Spatial & Temporal Concepts**





More Space-Time Concepts...

- *Configuration*
- *Linear Systems*
- *Non-Linear Dynamics*
- *Contingent*
 - *Spatial contingencies (configuration)*
 - *Historical contingencies (antecedent conditions)*
- *Emergent*
- *Complex-Response*

Linkages between Space & Time

Table 1 Frissel et al. (2006)

DOI: [10.1007/BF01867358](https://doi.org/10.1007/BF01867358)

Table 1. Some events or processes controlling stream habitat on different spatiotemporal scales.

System level	Linear spatial scale ^a (m)	Evolutionary events ^b	Developmental processes ^c	Time scale of continuous potential persistence ^a (years)
Stream system	10 ³	Tectonic uplift, subsidence; catastrophic volcanism; sea level changes; glaciation, climatic shifts	Planation; denudation; drainage network development	10 ⁶ –10 ⁵
Segment system	10 ²	Minor glaciation, volcanism; earthquakes; very large landslides; alluvial or colluvial valley infilling	Migration of tributary junctions and bedrock nickpoints; channel floor downwearing; development of new first-order channels	10 ⁴ –10 ³
Reach system	10 ¹	Debris torrents; landslides; log input or washout; channel shifts, cutoffs; channelization, diversion, or damming by man	Aggradation/degradation associated with large sediment-storing structures; bank erosion; riparian vegetation succession	10 ² –10 ¹
Pool/riffle system	10 ⁰	Input or washout of wood, boulders, etc.; small bank failures; flood scour or deposition; thalweg shifts; numerous human activities	Small-scale lateral or elevational changes in bedforms; minor bedload resorting	10 ¹ –10 ⁰
Microhabitat system	10 ⁻¹	Annual sediment, organic matter transport; scour of stationary substrates; seasonal macrophyte growth and cropping	Seasonal depth, velocity changes; accumulation of fines; microbial breakdown of organics; periphyton growth	10 ⁰ –10 ⁻¹

^a Space and time scales indicated are appropriate for a second- or third-order mountain stream.

^b Evolutionary events change potential capacity, that is, extrinsic forces that create and destroy systems at that scale.

^c Developmental processes are intrinsic, progressive changes following a system's genesis in an evolutionary event.

Geomorphic Spatial Scales Tied to Time

Table 2.1 A nested hierarchy of geomorphic scales

Scale	Evolutionary adjustment timeframe (yr)	Disturbance event frequency (months)	Geomorphic influence
Catchment	10^5 – 10^6	10^3	Tectonic influences on relief, slope and valley width combined with lithologic and climatic controls on substrate, flow and vegetation cover (among other factors) determine the imposed boundary conditions within which rivers operate. The drainage pattern and stream network influence the nature, rate and pattern of biophysical fluxes (these relationships are also fashioned by catchment geology, shape, drainage density, tributary–trunk stream interactions, etc). Vegetation cover and land use indirectly influence river character and behaviour through impacts upon flow and sediment delivery.
Landscape unit	10^3 – 10^4	10^2	Landscape units are readily identifiable topographic features with a characteristic pattern of landforms. The nature, rate and pattern of biophysical fluxes are influenced by landscape configuration (i.e. the pattern of landscape units and how they fit together in any given catchment) and the connectivity of reaches. At this scale, the channel, riparian zone, floodplain and alluvial aquifer represent an integrated fluvial corridor that is distinct from, but interacts with, the remaining catchment.

Geomorphic Spatial Scales Tied to Time

Table 2.1 A nested hierarchy of geomorphic scales

Scale	Evolutionary adjustment timeframe (yr)	Disturbance event frequency (months)	Geomorphic influence
Reach	10^1 – 10^2	10^1	Geomorphic river structure and function are relatively uniform at the reach scale. Morphological attributes such as channel planform and geometry are fashioned primarily by flow regime, sediment transport regime, floodplain character and vegetation and groundwater–surface-water exchange. Distinct assemblages of channel and/or floodplain landforms characterise reaches.
Geomorphic unit	10^0 – 10^1	10^0	These landform-scale features reflect formative erosional and depositional processes that determine river structure and function. Distinct features are evident in channel and floodplain compartments. Morphodynamic relationships fashion these landforms, where process influences form and vice versa.
Hydraulic unit	10^{-1} – 10^0	10^{-1}	This scale of feature is determined by (and shapes) flow–sediment interactions that reflect the energy distribution along a river course. Relationships vary markedly with flow stage. Pronounced local-scale variability in surface roughness, flow hydraulics or sediment availability and movement may be evident around basal materials, logs and organic debris. Surface–subsurface flow linkages fashion hyporheic zone processes.

Key Concepts in Fluvial Geomorphology

- I. Intro
- II. Spatial Considerations
- III. Conceptualization of Time
- IV. Combining Spatial & Temporal Concepts





  JOE WHEATON

Next Time

In Chapter Three, we'll zoom out and focus on "Catchment Scale Controls"